IM198-CD
Rev. B

OPERATION &
INSTALLATION MANUAL

SYSTEM IIA AUTOMATIC
POWER METER
CALIBRATION SYSTEM

This owner's manual was as current as possible when this product was manufactured. However, products are constantly being updated and improved. Because of this, some differences may occur between the description in this manual and the product you received.

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SAFETY SUMMARY

DEFINITIONS

The following definitions apply to WARNINGS, CAUTIONS, and NOTES found throughout this manual.

WARNING

An operating or maintenance procedure, practice, statement, condition, etc., which, if not strictly observed, could result in injury and/or death of personnel. Do not proceed beyond a WARNING symbol until all the indicated conditions have been fully understood and/or met.

CAUTION

An operating or maintenance procedure, practice, statement, condition, etc., which, if not strictly observed, could result in damage or destruction of the equipment or long-term health hazards to personnel. Do not proceed beyond a CAUTION symbol until all the indicated conditions have been fully understood and/or met.

NOTE

An essential operating or maintenance procedure, condition, or statement that must be highlighted.

GENERAL PRECAUTIONS

The following are general precautions that are not related to any specific procedure and, therefore, do not appear elsewhere in this publication. These are precautions that personnel must understand and apply during various phases of instrument operation or service.

WARNING

- Potentially lethal voltages are present in this instrument. Serious shock hazards from voltages above 70 volts may exist in any connector, chassis, or circuit board.
- Use the buddy system any time work involving active high voltage components is required. Turn OFF the power before making/breaking any electrical connection. Regard any exposed connector, terminal board, or circuit board as a possible shock hazard. DO NOT replace any component or module with power applied.
- If test conditions to live equipment are required, ground the test equipment before probing the voltage or signal to be tested.
- Personnel working with or near high voltage should be familiar with modern methods of resuscitation.
- DO NOT wear jewelry (rings, bracelets, metal watches, and/or neck chains) while working on exposed equipment. Be very cautious about using hand tools near exposed backplanes, bus bars, and/or power supply terminals. Use properly insulated tools. When making test connections to the power supply terminals and bus bars; use only insulated probe tips.
- Verify that the instrument is set to match the available line voltage and the correct fuse is installed.
- DO NOT install substitute parts or perform any unauthorized modification to this instrument. Contact TEGAM to acquire any information on replacement parts or

returning the instrument for repair. Unauthorized modification can cause injury to personnel and/or destruction of the instrument.

- Operating personnel must not remove instrument covers. Component replacement or adjustments MUST BE performed by qualified service personnel.
- DO NOT operate the instrument near or in the presence of flammable gases or fumes.

DETAILED PRECAUTIONS

The following WARNINGS, CAUTIONS and NOTES appear throughout the text of this manual and are repeated here for emphasis.

WARNING

Sufficient power levels are present at the Power Input Assembly to cause personal injury. Ensure that the System IIA power cord is DISCONNECTED before attempting to change fuses.

DO NOT connect or apply power to this instrument until the Power Input Assembly has been adjusted to the correct operational line voltage.

Ensure that the Signal Source RF power is OFF before removing or installing any component or instrument into any setup.

CAUTION

All procedures and steps identified as must be followed exactly as written and according to ESDS device handling procedures in IM-211 or other accepted ESDS procedures. Failure to comply WILL RESULT in ESDS damage.

DO NOT use a nylon bristle brush in the solvent as the bristles may dissolve and cause damage to the circuit card or component.

DO NOT bend pins of electrical connectors when using fiber-bristle brush.

Compressed air used for cleaning and/or drying can create airborne particles that may enter the eye. Goggles/faceshields should be worn. DO NOT direct air stream towards self or other personnel. Pressure should be restricted to a maximum of 15 psi to avoid personal injury.

Under no circumstances use a wire brush, steel wool, or abrasive compound. Using these items will cause extensive damage to the instrument surface.

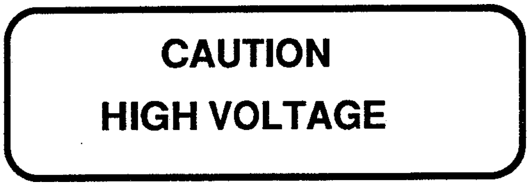
NOTE

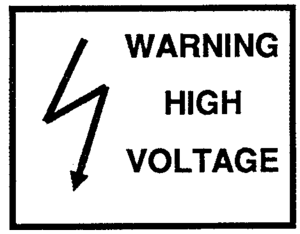
DO NOT return any instrument or component to TEGAM without receiving prior factory authorization.

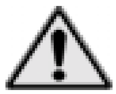
To facilitate installation, bag and mark all mounting hardware and tag all wires/cables during removal with sufficient information to allow reconnection. Then remove tag after installation. This is recommended to ensure proper installation of the component or assembly.

SAFETY SYMBOLS

Refer to the applicable instrument O & S manual for any symbols used to identify safety hazards found throughout this publication and/or located on the instruments. Some are shown below:


CAUTION
HIGH VOLTAGE


WARNING
HIGH
VOLTAGE



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SECTION I INTRODUCTION AND GENERAL DESCRIPTION

INTRODUCTION

PURPOSE

This manual provides Operation and Service instructions necessary to set up, service, test, troubleshoot, calibrate and operate the TEGAM System IIA Automatic Power Meter Calibration System. The manual also provides component location, reference designators and nomenclature to identify all the assemblies and system configurations of the System IIA.

Figure 1-1 Automatic Power Meter Calibration System

SCOPE

This manual is to be used in conjunction with the operation and maintenance of the System IIA, Automatic Power Meter Calibration System. The manual also provides a description of each system instrument; testing of the system; maintenance procedures to maintain the instruments; and troubleshooting to a system instrument or component.

ARRANGEMENT

The information contained in this manual is tabulated in the Table of Contents, List of Illustrations, and List of Tables. The manual is divided into five sections, listed as follows:

SECTION I Introduction and General Description

SECTION II Installation and Shipment

SECTION III Theory &Operating Instructions

SECTION IV Maintenance

SECTION V Performance Testing, Calibration & Troubleshooting

RELATED MANUALS

The following manuals contain information that may be used in conjunction with this manual to operate, service, or calibrate the System IIA.

Manual	Title
H4-1 and H4-2	Federal Supply Code for Manufacturers Cataloging Handbook
IEEE STD 470-1972	Application Guide for Bolometric Power Meters
IM-128	Models 1109, 1109H and 1110 Coaxial Power Standards, Operation and Service Manual

IM-140	Model 1806 Dual Type IV Power Meter Operation and Service Manual
IM-199	Model 1807A RF Transfer Standard, Operation and Service Manual
IM-200	Model 1805B RF Control Unit, Operation and Service Manual
IM-203	Model 1107-7 and 1107-8 RF Power Transfer Standards, Operation and Service Manual
IM-205	Models 1111 and 1116 Coaxial Power Standards, Operation and Service Manual
IM-241	Models 1119, 1119H & 1120 Coaxial Power Standards, Operation and Service Manual
IM-245	Models 1117A & 1118 Coaxial Power Standards, Operation and Service Manual
IM-249	Operation Manual, SWR Measurement Kit (P/N 187-4003)
IM-255	Operation Manual, 50-75 W Min, Loss Matching Pad (P/N 138-650)
IM-267	Model 1727A, Amplifier, Operation and Service Manual
IM-273	SCAL Software Operations Manual

CONTACTING TEGAM

In the event of an instrument malfunction, contact TEGAM. An apparent malfunction of an instrument or component may be corrected over the phone by contacting TEGAM. **DO NOT** send the instrument or component back to the factory without prior authorization. When it is necessary to return an item, state the symptoms or problems, catalog and type number of the instrument or component, serial number of the item, and date of original purchase. Also write the company name, your name, and phone number on an index card. Then attach the card to the instrument or component to be returned. Or contact TEGAM using the following:

TEGAM, INC.
TEN TEGAM WAY
GENEVA, OH 44041 USA

800-666-1010 toll-free
440-466-6100 phone
440-466-6110 fax

SAFETY CONSIDERATIONS

The System IIA and all related documentation must be reviewed for familiarization with safety markings and procedures before performing any operation and/or service. Refer to the SAFETY SUMMARY located at the beginning of this manual for a summary of safety information and procedures. Following these simple safety precautions will ensure safe operation and service of the System IIA.

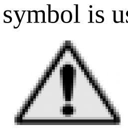
ABBREVIATIONS AND ACRONYMS

The following list contains all abbreviations used throughout this manual. Abbreviations and acronyms that are not listed conform with MIL-STD-12D.

ASSY	Assembly
CW	Continuous Wave
DUT	Device Under Test
ESDS	Electrostatic Discharge Sensitive

ELECTROSTATIC DISCHARGE SENSITIVE

The equipment documented in this manual contains certain Electrostatic Discharge Sensitive (ESDS) components or parts. Therefore, certain procedures/steps are identified by the use of the symbol . This symbol is used in two ways:



All procedures and/or steps identified as must be followed exactly as written and according to ESDS device handling procedures in IM-211 or other accepted ESDS procedures. Failure to comply **WILL RESULT** in ESDS damage.

a. When the ESDS symbol is placed between a paragraph number and title, all of that paragraph, including all subparagraphs, is considered an ESDS device handling procedure.

b. When the ESDS symbol is placed between a procedure/step number and the text, all of that procedure is considered an ESDS device handling procedure.

GLOSSARY OF TERMS

Appendix B located at the end of this manual provides a short list of terms commonly used in RF and Microwave power calibration.

GENERAL DESCRIPTION

DESCRIPTION OF EQUIPMENT

The following paragraphs provide a general description of the System IIA, Automatic Power Meter Calibration System (shown in Figure 1-1).

Functional Description

The System IIA is basically an IEEE-488 bus controllable system designed to calibrate power meter sensors over the 0.01 to 18.0 GHz frequency range. Using different mounts, the System IIA frequency range is expandable to cover 0.1 to 100 MHz, 100 kHz to 4.2 GHz, 0.05 to 26.5 GHz in coaxial and 18 to 40 GHz using waveguide standards. System IIA provides accurate measurements for standard calibration points that are directly traceable to the National Institute of Standards and Technology (NIST).

The System IIA is comprised of two functional parts; a Precision Power Source and a Precision Power Meter. The Precision Power Source (Figure 1-2) provides an accurately known power level for comparison with the value measured by the Device Under Test (DUT). The Precision Power Meter (Figure 1-3) provides the means for measuring RF power levels and for transferring calibration to feedthrough mounts or power sensors. Refer to Section III for a further discussion of the System IIA and its many functions.

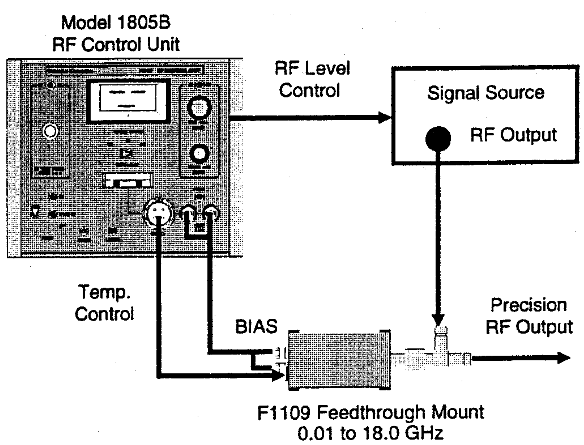


Figure 1-2 Feedthrough Power Source

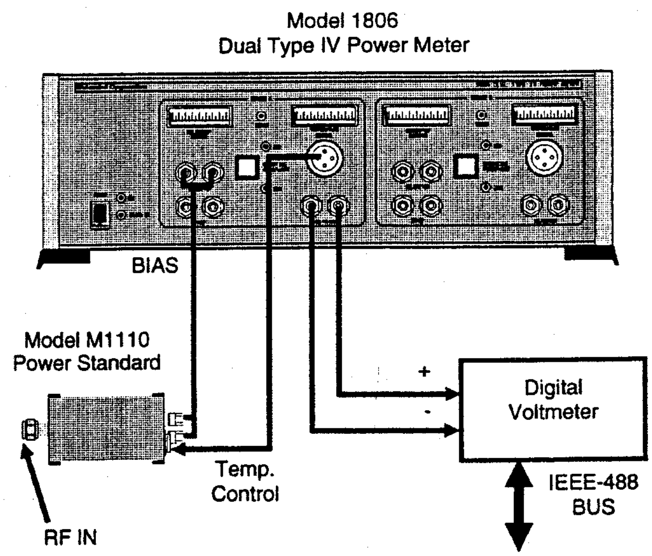


Figure1-3 Precision Power Meter

Physical Description

The System IIA is supplied in many different hardware configurations with a variety of Model numbers, Figure 1-4 provides a listing of all System IIA model numbers and included hardware/software. For physical descriptions and electrical specifications of each system component as a stand-alone instrument, reference the applicable Operation and Service Manual. The System IIA components can be easily stacked with other TEGAM instruments or mounted in any cabinet or rack designed according to EIA RS-310 and MIL-STD-189

APPLICATIONS

The System IIA was designed primarily for the transfer of calibration factors to power meter sensors (Figure 1-5 shows a typical application). However, the System IIA components have many other applications such as measuring mixer compression; calibrating the linearity of receivers and attenuators; comparing power standards; spectrum analyzer calibration, and to measure effects of noise on linearity at low signal levels. Virtually any application requiring a precision-leveled power source or precision power measurements is a prime candidate for System IIA. The following paragraphs outline several applications for System IIA.

Figure 1-6 shows a calibration setup using a Model 1727A RF Amplifier and a +10 dBm RF Signal source to increase the output power so that the System IIA Precision Power Source can perform calibrations from 1 mW to 10 mW in the 0.01-18.0 GHz frequency range.

Figure 1-7 shows a measurement setup using the Model 1806, 1110 or 1111 mount and a Weinschel Model 8300-2 that can be used to verify the linearity of microwave receivers. Refer to TEGAM Application Note #208 for more details.

Figure 1-8 shows an example of how the precision power source can be configured with a Weinschel Model 8300-2 to perform reference verification and calibration of spectrum analyzers.

Figure 1-9 shows a precision power source using the TEGAM M1111 feedthrough mount to allow the user to calibrate Power Sensors or other devices operating in the 0.1 to 100 MHz range. This can be extended to cover the 0.1 MHz to 4.2 GHz (F1119), and 0.05 to 26.5 GHz (Model F1117A) frequency ranges using the appropriate generators.

Model	Description	Basic System IIA-B	Basic System IIA-B-807	Intermediate System IIA-B	Intermediate System IIA-B-807	Advanced System IIA-B	Advanced System IIA-B-807	Basic System IIA-C	Basic System IIA-D
1805B	RF Level Controller	*	*	*	*	*	*		
1806	Dual Type IV Power Meter	*	*	*	*	*	*	*	*
F1109	Feedthrough Thermistor Mount*	*		*		*			
1807A	Cabinet Assembly with F1109 Power Standard*		*		*		*		
M1110	Terminating Thermistor Mount	*	*	*	*	*	*		
1585-1000	Low Loss RF Cable 3 ft	*	*	*	*	*	*		
1585-1008	Cable Assembly 3.5 mm							*	*
1585-1009	Cable Assembly 2.92 mm							*	*
189-31	Sensor Calibration Program for Windows	*	*	*	*	*	*	*	*
138-645	Calibration Accessory Kit (includes calibrated attenuators/adapters for Type N)	*	*	*	*	*	*		
IM-198	Operation and Instruction Manual	*	*	*	*	*	*	*	*
**	0.01 – 20 GHz Signal Source			*	*	*	*		
3458A	Digital Multimeter/Voltmeter (HP3458A)					*	*		
***	IBM Compatible Computer					*	*		
1583-6	GPIB Interface					*	*		
1107-7	2 Meter IEEE Cables (3 ea)							*	
001-206	Waveguide Isolator 18-26.5 GHz							*	
1107-8	Power Transfer Standard, 18-26.5 GHz WR-42 W/G								*
001-120	Waveguide Isolator, 26.5 – 40 GHz								*

NOTES:
* Other mounts may be added or offered as a substitute to any of the systems listed above to increase or change frequency coverage.
** Signal Source Brand and Model is based on customer choice, vendor availability and compatibility with system software.
*** Computer Brand and Model is based on customer choice, vendor availability and compatibility with system software.

All versions of System IIA can be obtained with terminating mounts calibrated directly by the National Institute of Standards and Technology. Delivery of these Systems is determined by NIST calibration schedules which can add up to four months to factory availability. Contact factory for price and delivery of this service. In applications where several systems are to be deployed, traceability may be supported by a single terminating mount. In this case, the fielded systems can be specified without the thermistor mount by adding the suffix NK1 to the model number.

BASIC SYSTEM: The Basic System IIA is comprised of the Models 1805B RF Control Unit, the Model 1806 Dual Type IV Power Meter, Calibration Accessory Kit, two Type N Thermistor Mounts (Feedthrough and Terminating), a 3 ft. Low Loss RF Cable, and Sensor Calibration software for Windows ™ .

INTERMEDIATE SYSTEM: This system adds a customer selected RF Signal Source. Consult sales representative for price and delivery.

ADVANCED SYSTEM: This system includes all components of the Intermediate system plus a PC compatible controller with GPIB Interface, three 2 meter IEEE-488 bus cables and 8-1/2 digit IEEE-488 bus controllable voltmeter.

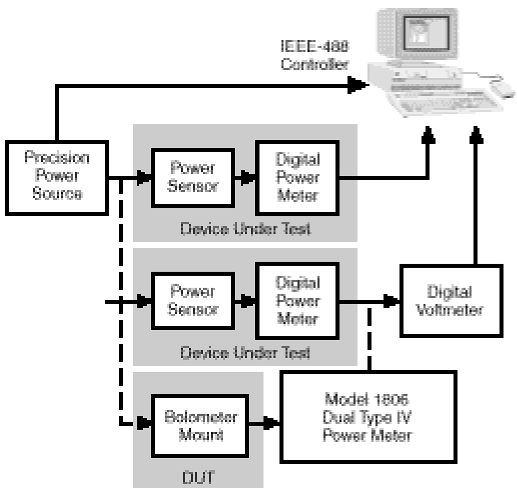
Windows ™ is a registered trademark of Microsoft Corporation.

Figure1-4 System IIA Model Number Matrix

Figure 1-10 shows a calibration setup using a TEGAM Model 1107-7 or 1107-8 waveguide mount to allow the user to calibrate Power Sensors or other devices in the 18 to 26.5 GHz (1107-7) or 26.5 to 40 GHz frequency range. Make note that the signal source must cover these frequency ranges.

Figure 1-11 shows a block diagram of a fully automated System IIA using the Model 1727A to provide 1 and 10 mW calibrations over the 100 kHz to 26.5 GHz frequency range. The Model 1727A provides two generator inputs that can accept a 100 kHz to 26.5 GHz signal range. Refer to IM-245 for details.

Figure 1-12 shows the Model 1727A used as part of the System IIA Precision Power Source to perform calibrations @ 100 mW over the 100 kHz to 18 GHz frequency range. The Model 1727A provides two generator inputs that can accept a 100 kHz to to 26.5 GHz signal. Refer to IM-245 for more details.



Power meters are automatically calibrated by System IIA. Digital power meters with bus output may be connected directly to the controller. Analog power meters that have an external output port may be calibrated by connecting them to the controller through a digital voltmeter. A digital power meter without IEEE option may be used via DVM.

Figure 1-5 System IIA Applications

Figure 1-13 illustrates a setup where two generators can be connected to the Model 1727A to provide continuous calibrations on sensors that cross the input frequency bands such as those that operate from 100 kHz to 4.2 GHz. Refer to IM-245 for more details.

Figure 1-14 shows the TEGAM System IIA's Precision Power Source setup to measure SWR/Return Loss using the SWR Measurement Kit (187-4003). The technique involves performing several "calibrations: of the sensor or mount, with open and/or short attached to the Return Loss bridge test port, and then with the DUT attached.

Figure 1-15 shows the TEGAM System IIA Precision Power Source configuration using a 50-75 ohm Minimum Loss Matching Pad (138-650) to measure and calibrate 75 ohm sensors over the 0.1 MHz-2.7 GHz frequency range.

SPECIFICATIONS

Table 1-1 lists specifications to be considered when using the System IIA, Automatic Power Meter Calibration System. Other specifications for the individual instruments can be located in the specific O & S manual.

RECOMMENDED MATERIALS

Table 1-2 provides a list of recommended consumables to be used when cleaning or servicing System IIA.

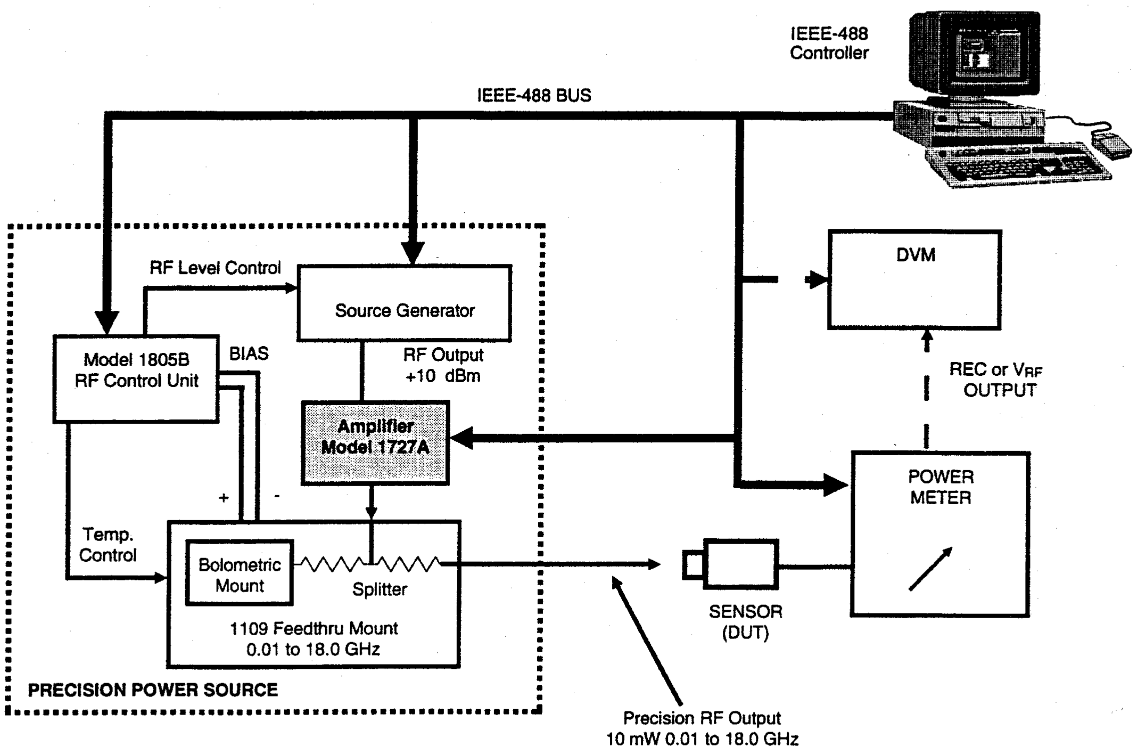


Figure 1-6 10 mW Configuration using Model 1727A

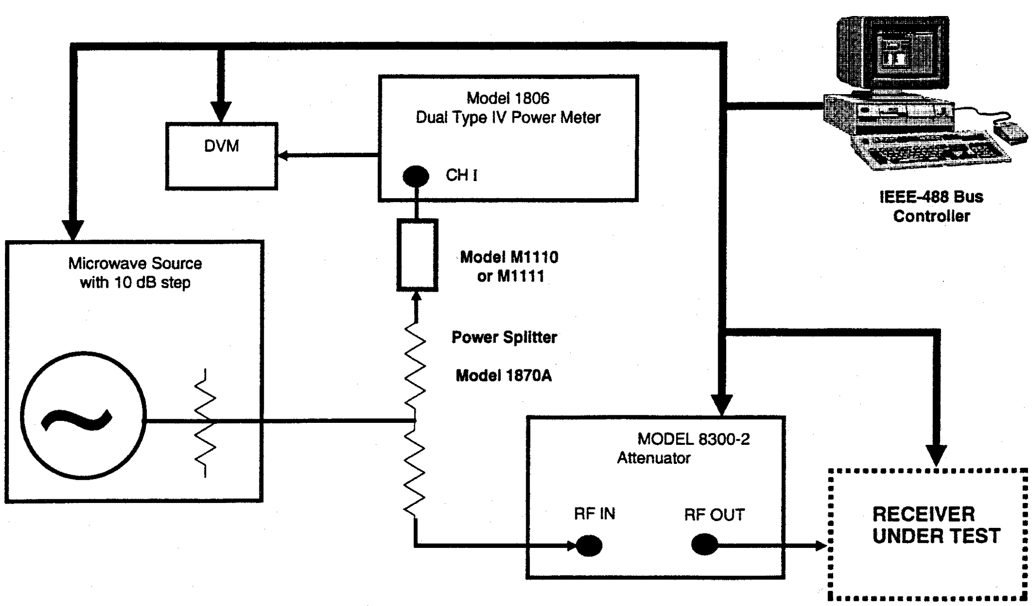


Figure 1-7 Receiver Linearity Verification Setup

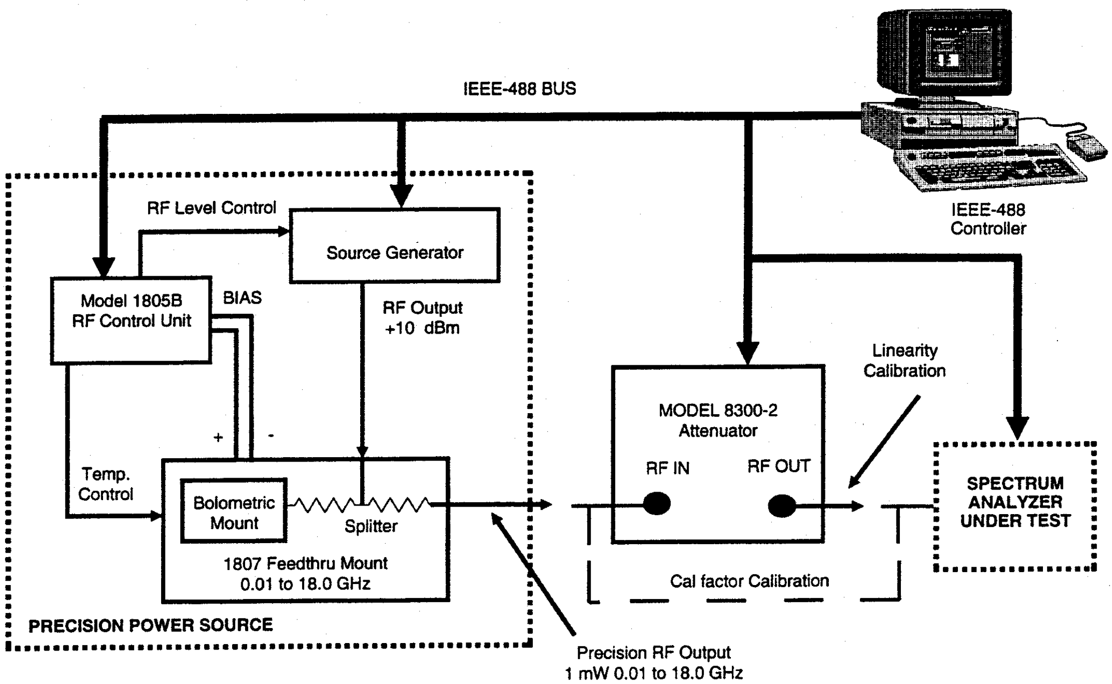


Figure 1-8 Spectrum Analyzer Calibration Setup

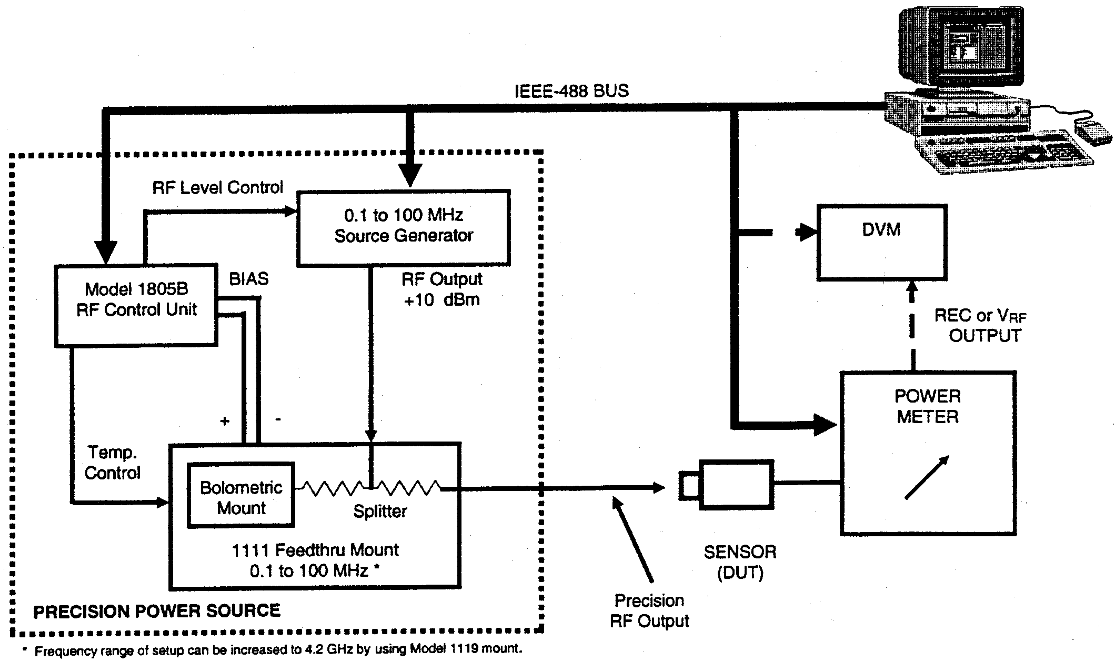


Figure 1-9 0.1-100 MHz Power Sensor Calibration Setup

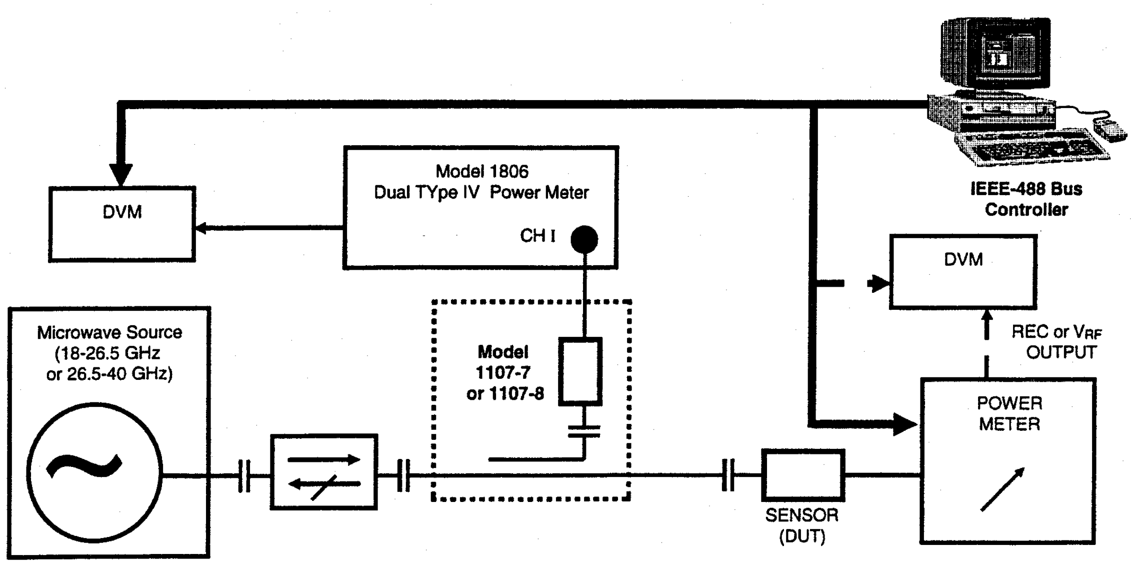


Figure 1-10 18-40 GHz Calibration Setup

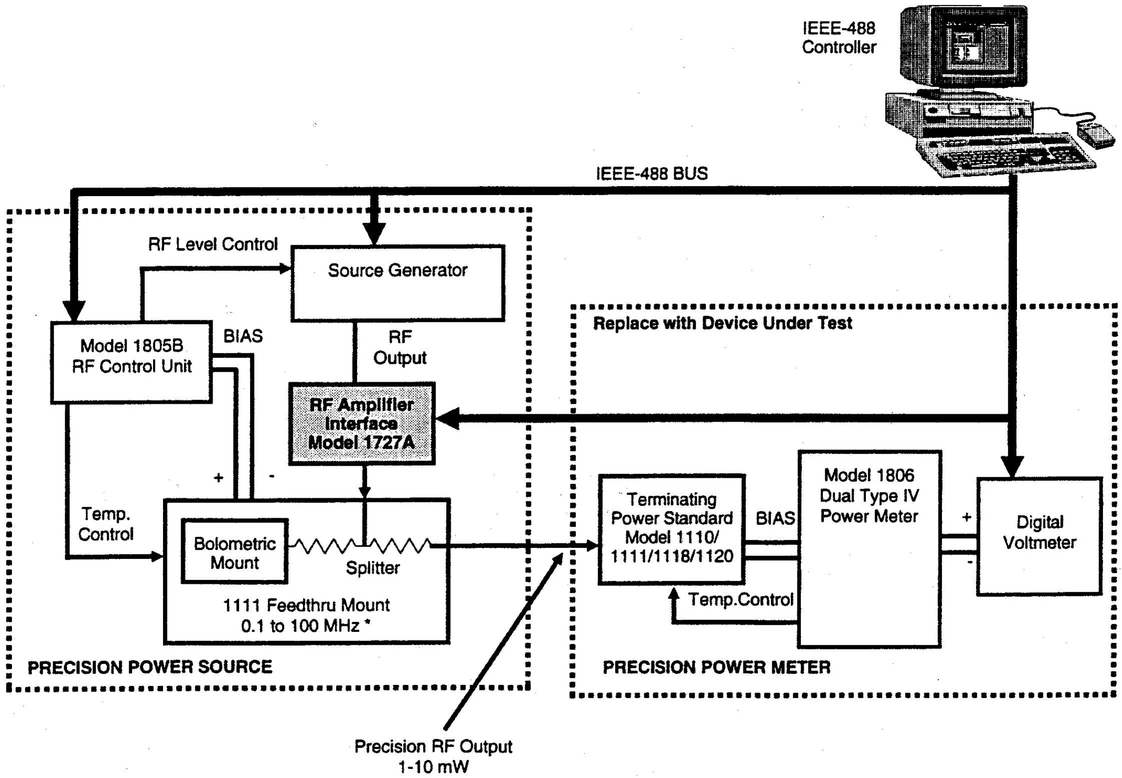


Figure 1-11 System IIA Configuration using Model 1727A

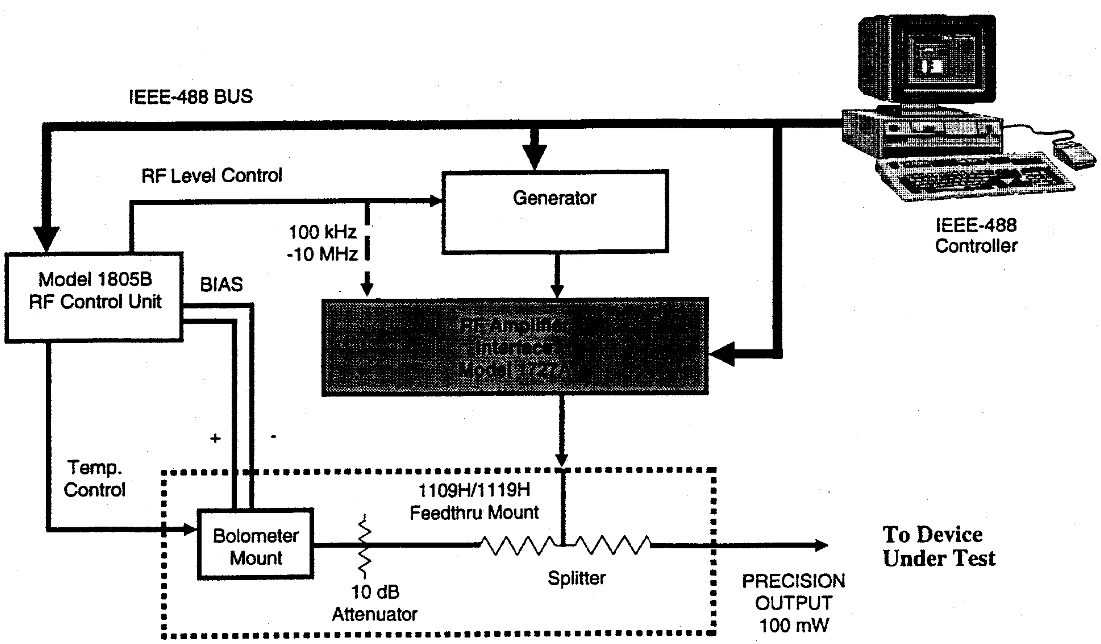


Figure 1-12 Typical 100 mW Setup using Model 1727A

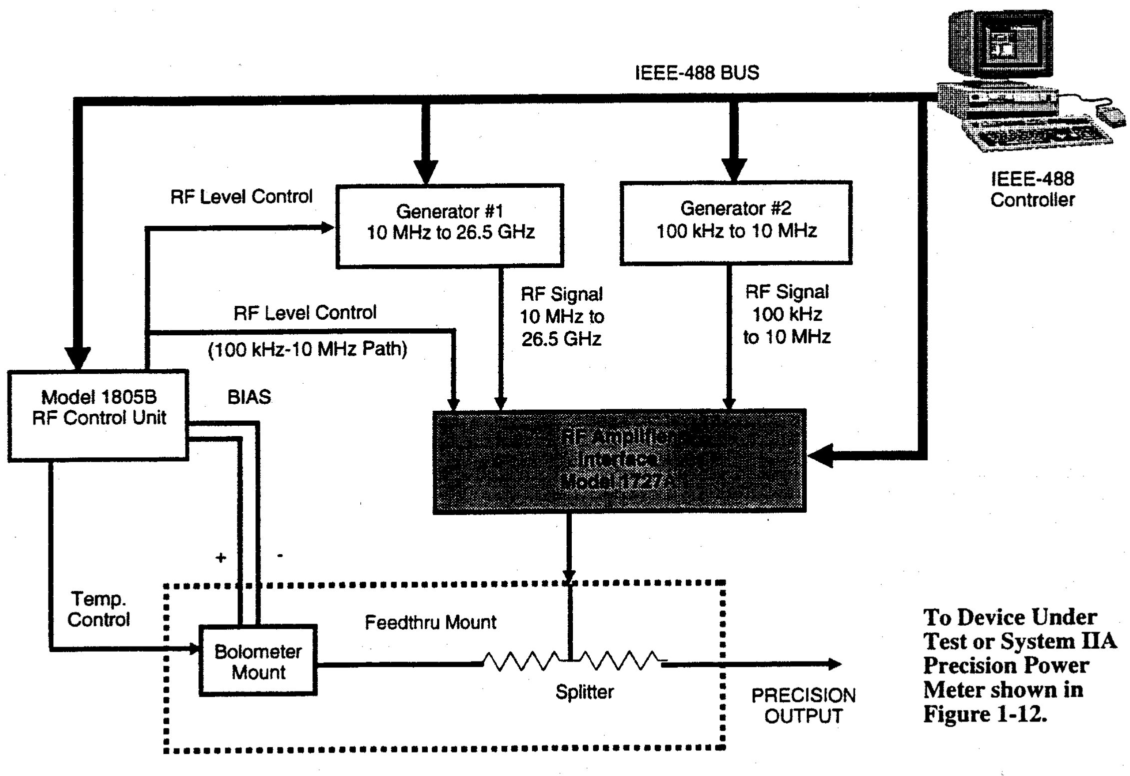


Figure 1-13 Model 1727A Setup using two Generators

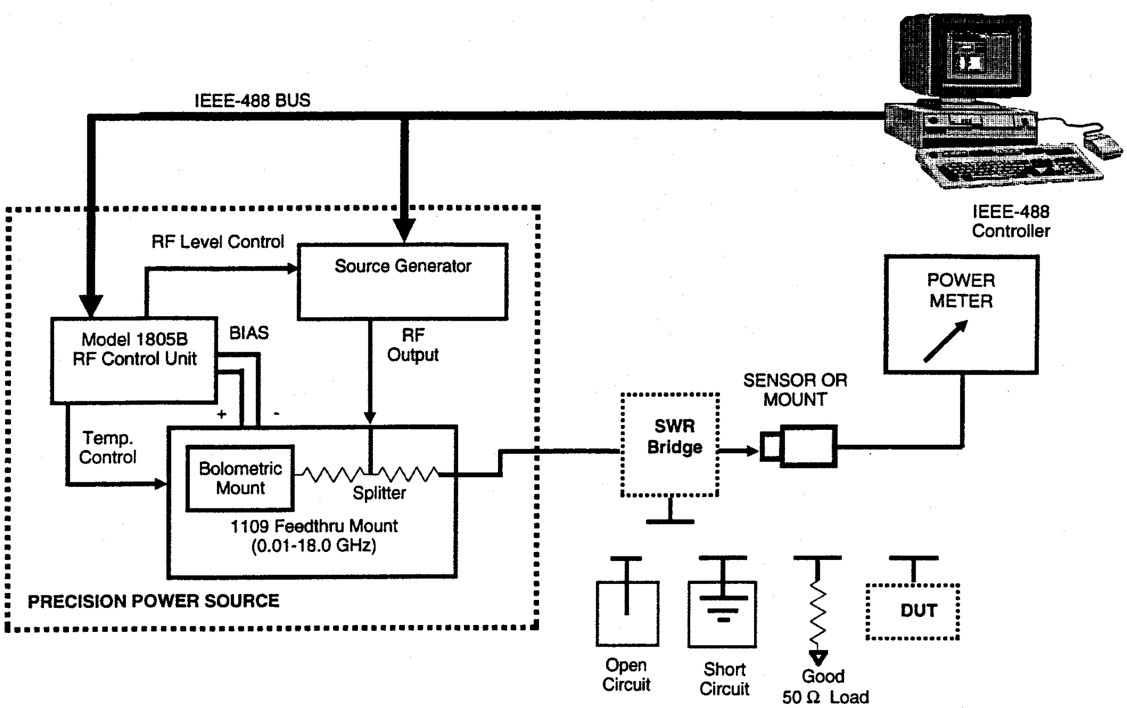


Figure 1-14 SWR/Return Loss Measurements

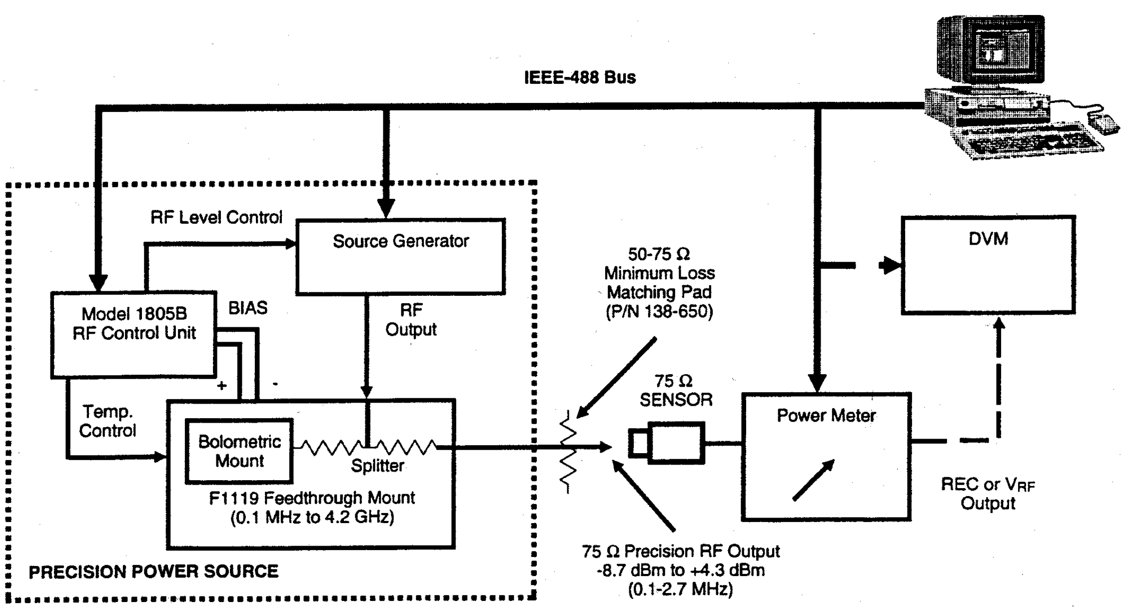


Figure 1-15 75 Ohm Sensor Calibration Setup

SPECIAL TOOLS AND TEST EQUIPMENT

All recommended special tools and test equipment to be used with the System IIA are listed in Table 1-3.

AVAILABLE ACCESSORIES

The following list contains available accessories for System IIA.

Part/Model #	Description
190-499	Rack Mount Adapters for Model 1806
138-606	Rack Adapter and Side Panels for Chassis Slides, Model 1806
138-486	Rack Adapters (additional mounting hardware required)
138-645	Kit, Calibrated Attenuators and Adapters for Type N
138-650	50-75 Ohm Minimum Loss Matching Pad with S Parameter Data
138-652	Cable Assembly, Compensated Mount Calibration
187-4003	SWR Measurement Kit
189-31	Sensor Calibration Lab (SCAL) System II Software for Windows™ (refer to Section III for controller hardware requirements).
1109H	Feedthrough Mount, 0.01 –18 GHz, 100 mW
1111	Feedthrough Mount, 0.1-100 MHz
1116	Terminating Mount, 0.1-100 MHz
1117A	Feedthrough Mount, 0.5-26.5 GHz
1118	Terminating Mount, 0.5-26.5 GHz
1119	Feedthrough Mount, 100 kHz-4.2 GHz
1119H	Feedthrough Mount, 100 kHz-4.2 GHz, 100 mW
1120	Terminating Mount, 100 kHz-4.2 GHz
1807A	RF Transfer Standard, 0.01-18.0 GHz
1107-7	Waveguide Mount (Feedthrough or Terminating), 26.5-40.0 GHz, WR-42.
1107-8	Waveguide Mount (Feedthrough or Terminating), 26.5-40.0 GHz, WR-28
1727A	RF Amplifier (100 kHz-26.5 GHz)
1919	Rack Adapter Kit (allows any two 1805B, 1807 or 1808 instruments to be mounted in the same rack configuration).

CUSTOM CONFIGURATIONS

System IIA's versatility allows the user and TEGAM to create or design different types of power measurement and calibration systems to meet many specific customer applications such as Spectrum Analyzer and receiver calibration systems; High power calibration systems; and calibrate a wide variety of power sensors and other devices. For information about System IIA and/or other TEGAM products, contact the Sales Department at TEGAM.

Table 1-1 System IIA Specifications

SPECIFICATION	**DESCRIPTION**
INPUT POWER REQUIREMENT	100, 120, 220, 240 Vac ±10%: 48 to 62 Hz (all Instruments)
ENVIRONMENTAL	Operating Temperature +10 to +40° C (+25 to +104° F) Storage Temperature -40 to +75° C (-40 to +167° F) Humidity less than 95% Recommended +22 ±1° C (+73 ±2° F) @ 40% RH
FREQUENCY RANGE	0.01 - 18 GHz, standard System IIA (F1109, M1110) - Type N 0.01 - 18 GHz, 100 mW expanded System IIA (1109H) - Type N 0.1 - 100 MHz, expanded System IIA (1111, 1116) - Type N 0.1 MHz - 4.2 GHz, expanded System IIA (1119, 1120) - Type N

	0.1 MHz - 4.2 GHz, 100 mW expanded System IIA (1119H) - Type N 0.05 - 26.5 GHz, expanded System IIA (1117A, 1118) -3.5 mm 18 - 26.5 GHz, expanded System IIA (1107-7) - WG42 26.5 - 40 GHz, expanded System IIA (1107-8) - WG28
IMPEDANCE	50 Ω nominal
CALIBRATION FACTOR STABILITY	< 0.5% per year
CALIBRATION FACTOR POWER DEPENDENCE	< 0.1% from 1 mW, negligible to maximum useful limit
CALIBRATED POWER LEVEL RANGE	0.5 µW to 100 mW
POWER MEASUREMENT RANGE	10 µW to 25 mW
RESISTANCE AT BIAS	200 Ω
TEMPERATURE COEFFICIENT OF RESISTANCE	Negative
CALIBRATION	Individual calibrations traceable to NIST supplied at following frequencies: 10 - 100 MHz in 10 MHz Steps 100 MHz - 2.0 GHz in 50 MHz increments 2.1 - 4.0 GHz in 100 MHz increments 4.2 - 12.4 GHz in 200 MHz increments 12.75 - 18.0 GHz in 250 MHz increments 18.0 - 26.0 in 1 GHz increments, plus 26.5 GHz 27.0 - 40.0 in 1 GHz increments, plus 26.5 GHz
POWER SENSITIVITY OF RESISTANCE	-13 Ω/mW

Table 1-2 Recommended Consumable Materials

ITEM NUMBER	NOMENCLATURE	MATERIAL	SPECIFICATION NUMBER
1	Acid Brush (Fiber-Bristle)		H-B-643 Type II CLASS I
2	Aluminum Wool		MIL-A-4864A
3	Brush, Soft-Bristle		H-B-420 Type II
4	Cleaner/Solvent	Isopropyl Alcohol	TT-1-735A (3)
5	Cloth, Lint Free		MIL-C-85043 Type IIA

Table 1-3 Special Tools and Test Equipment

Tool/ Equipment/ Model Number	Nomenclature	Use and Application
PC System Controller	IBM PC or compatible (486 processor or higher) with hard drive, 16 Meg RAM, color monitor, and IEEE-488 Bus interface. Operating System must be Windows 3.1 or higher.	IEEE-488 Bus Control System IIA-A, System IIA-B, System IIA-AS, System IIA-BS, and all setups
HP3458A	Digital Voltmeter, 8 ½ digit IEEE-488 bus controllable (2 required if using a 1107-7 or 1107-8)	System Calibration Setups and Power Sensor Calibration for Waveguide Bands (18-26.5 GHz & 26.5-40 GHz)
001-120	WR-28 Waveguide Isolator	26.5-40 GHz Calibration Setup
001-206	WR-42 Waveguide Isolator	18-26.5 GHz Calibration Setup
TEGAM 1116 & 1111	Thermistor Mount (Power Standard)	0.1-100 MHz Calibration Setup
TEGAM 1119 & 1120	Thermistor Mount (Power Standard)	100 kHz-4.2 GHz Calibration Setup

TEGAM 1117A & 1118	Thermistor Mount (Power Standard)	0.05-26.5 GHz Calibration Setup
Gigatronics 6060B	Signal Source 0.1-1040 MHz	0.1-100 MHz Calibration Setup
Gigatronics GT9000, Anritsu 68047B or HP 83620B	Synthesized CW Signal Source, 0.01-18 GHz, +10 dBm	Signal Source for System IIA-A System IIA-B and all setups
Anritsu 68059B or HP 83630B	Synthesized CW Signal Source, 0.05-26.5 GHz +10 dBm	Signal Source for 0.05-26.5 GHz setups
Anritsu 68069B or HP 83640B		18-26.5 GHz Calibration Setup
TEGAM 1107-7	Waveguide Thermistor Mount (Power Standard)	18-26.5 GHz Calibration Setup
Anritsu 68069B or HP 83640B		26.5-40 GHz Calibration Setup
TEGAM 1107-8	Waveguide Thermistor Mount (Power Standard)	26.5-40 GHz Calibration Setup
Any	Torque Wrench, 14 ± 1 inch pounds (Type N)	Connector Coupling Torque Type N Connectors
Any	Torque Wrench, 7 ± 1 inch pounds (SMA, 3.5 mm)	Connector Coupling Torque SMA, 3.5 mm

SECTION II INSTALLATION AND SHIPMENT

GENERAL

This section contains all necessary instructions and information to install and interface the System IIA Automatic Power Meter Calibration System. Included in this section is initial inspection; power requirements; preparation for use; and shipping instructions.

INITIAL INSPECTION

The System IIA instruments were carefully inspected both mechanically and electrically before shipment. These instruments should be free of mars or scratches and in perfect electrical order upon receipt. After unpacking the instruments do not discard the shipping and packing material until the instruments have been visually inspected and it is determined that reshipment is not necessary. Perform initial inspection in accordance with the following paragraphs.

Inspection

Perform the following procedures before removing any item from the shipping container.

a. Visually inspect the shipping container for any discoloration; stains; charring; or any other signs of exposure to heat, moisture, or liquid chemicals.
b. Check for any physical damage to the shipping container such as dents, large snags or rips, crushed sections or areas, and/or similar signs of excessive shock caused by careless handling.
c. Carefully remove the instrument and all other items from the shipping container.
d. Inventory all items against the packing list.
e. Inspect the instrument for any dents, cracks, deep scratches, damaged or loose switches and/or knobs, and any other signs of careless handling.

Damage

If it has been determined shipping damage has occurred, immediately contact the delivering carrier to perform an inspection and prepare a concealed damage report. Do not destroy any shipping or packing material until an agent of the carrier has examined it. Also notify TEGAM to report the nature and extent of damage to the instrument. When contacting TEGAM, please provide model and serial number of instruments received, so that the necessary actions can be taken. DO NOT return the instrument until a claim for the damages has been established. If there is mechanical damage (not from shipping), the contents are incomplete, and/or the instrument does not function properly refer to Section I and notify TEGAM.

POWER REQUIREMENTS

TEGAM supplies a detachable, power cable (P/N 068-21) to connect a 100-, 120-, 220-, or 240 Vac (±10%) power source with a frequency between 48 to 62 Hz to the System IIA instruments. Refer to Initial Setup before applying any power to the instrument.

ENVIRONMENTAL REQUIREMENTS

The System IIA instruments operate best within their specifications at an ambient temperature of -10° to +40°C. Operating beyond these limits can affect the accuracy of the instruments and damage internal circuitry.

RECOMMENDED OPERATING ENVIRONMENT

Normal Calibration Laboratory best practice dictates that the environment should be closely controlled. This will minimize errors introduced by temperature and humidity changes. A nominal temperature of +22°C (+73.4°F) provides a good working condition. A tolerance of ±0.5°C gives allowable temperature spread. Controlled temperatures also stabilize the aging process of the standards.

It is also recommended that equipment be supplied with power from stabilized power supplies.

PREPARATION FOR USE

The following paragraphs provide mounting instructions, input/output options and Initial Setup for the System IIA Automatic Power Meter Calibration System.

MOUNTING INSTRUCTIONS

The System IIA instruments are shipped with four plastic feet mounted to the bottom cover, allowing the user to place the instruments on any bench or to stack with other TEGAM instruments. When the System IIA instruments are placed on a bench or table, these feet provides a level support. System IIA instruments can also be rack mounted using the following Rack Adapter Kits:

Model #	Rack Adapter Kit
1806	P/N 190-499, Rack Mount Adapters or P/N 138-606, Rack Adapter and Side Panels for Chassis Slides
1805B, 1807A or 1808	Model 1919, Rack Adapter Kit (allows any two instruments to be mounted in the same rack configuration)

INITIAL SETUP

The initial setup procedure for operating and servicing is as follows:

a. Perform inspection prior to connecting any System IIA instrument to any power source.
b. Ensure the Voltage Selector/Fuse Assembly on each instrument is adjusted to the proper voltage setting (refer to applicable O & S manual).
c. Check the external power source outputs are in accordance with Table 1-1, System IIA Specifications.
d. Set up equipment as shown in Figures 2-3 through 2-14 (these are recommended setups only). Connect all instruments to the external power source. Refer to Section III for system operation.
e. If desired, perform the operational checkout procedures (Section V) to ensure proper operation of the System IIA.

CAUTION

When placing the System IIA instruments with fans on a bench, ensure that there are at least two inches of space behind the instrument for adequate airflow. DO NOT set an instrument on its rear panel. This practice blocks the fan and prevents adequate airflow.

INPUT/OUTPUT OPTIONS

The following paragraphs provide a description of the connections that can be made to the System IIA Automatic Power Meter Calibration System. Figures 2-1 and 2-2 show the location of these connectors. For a description of a connector not covered by the following paragraphs, refer to the applicable Operation and Service manual for that instrument or component.

TEMPERATURE CONTROL Connector

This Connector is located on the front panel of the Models 1805B and 1806 is a four (4) pin threaded connector which provides the current required to control the internal temperature of the connected thermistor mount.

MOUNT BIAS Output Terminals

These Terminals are spade-lug connecting posts which are located on front panel of the Model 1805B. Present at these Terminals is the dc bias voltage to be applied to the thermistor mount (Models 1109, 1807A, 1116, 1117, 1119, 1107-7 or 1107-8). The red connector is for positive (+) dc power and the black connector is for negative (-) dc power.

MOUNT BIAS Input Terminals

These Terminals are spade-lug connecting posts which are located on the front panel of the Model 1807A, the rear of Models 1109 and 1116, 1117, 1119 or the top of Models 1107-7 and 1107-8. These Terminals provide a connection point for the dc bias voltage supplied by the Model 1805B or 1806. The red connector is for positive (+) dc power and the black connector is for negative (-) dc power.

BOLOMETER Terminals

These Terminals are spade-lug connecting posts which are located on the front panel of the Model 1806 which is used to supply a dc bias voltage to and from the thermistor mount (Models 1110, 1111, 1118, 1120, 1107-7 or 1107-8). The red connector is for positive (+) dc power and the black connector is for negative (-) dc power.

Mount SENSE Terminals

These Terminals are spade-lug connecting posts which are located on the front panel of the Model 1806. The dc voltage present at these Terminals is proportional to the effective dc current passing through the thermistor element. Use of the voltage potential present at these terminals reduces errors associated with lead resistance.

VOLTMETER Terminals

Voltmeter Connectors TP5 and TP6 are spade-lug-connecting posts. Placement of these connectors is in the lower right-hand corner of either bridge (shown in Figure 3-1 on Bridge B). TP5 and TP6 complete the dc path between the Model 1806 and a digital voltmeter with a 6.5-digit resolution. DC voltage present at TP5 and TP6 is equivalent to the voltage across the thermistor element. The red connector is for positive (+) dc power and the black connector is for negative (-) dc power.

RF INPUT Port Connector

This SMA female connector is located on the front panel of the Model 1807A and is used to pass the RF signal from the signal source directly to the power splitter. The RF Input is also a Type N or GPC-7 connector located on the front end of Models 1109, 1116, and 1119 thermistor mounts. 3.5 mm connectors are used on the Model 1117. Models 1107-7 and 1107-8 RF Inputs are waveguide WR-42 for Model 1107-7 and WR-28 for Model 1107-8. This RF Input connector can handle a maximum of 100 mW of RF power within the frequency range of the desired thermistor mounts.

TEST Port Connector

This Type N connector is located in the upper left corner of the 1807A front panel or on the power splitter of the Models 1109, 1116, and 1119 thermistor mounts. 3.5 mm connectors are used on the Model 1117. Models 1107-7 and 1107-8 RF TEST ports are waveguide WR-42 for Model 1107-7 and WR-28 for Model 1107-8. This connector provides an output for the Precision Power Source to the device under test or other thermistor mounts.

Temperature Control (MOUNT HEATERS) Connector

This connector is located on the front panel of the Models 1807A, the rear of all coaxial power standards, or the top of Models 1107-7 and 1107-8. This connector is a four (4) pin threaded connector which is used to apply the current supplied by the Model 1806 or 1805B to control the internal temperature thermistor mount.

IEEE-488 Interface Bus

Joining the System IIA to a system controller requires the connection of IEEE-488 control bus to the IEEE-488 INTERFACE BUS connector located on the rear panel of the instruments. The IEEE-488 INTERFACE BUS connector carries program command and data signals passing between the System IIA instruments and a system controller. For a description or more information about the IEEE-488 bus connector, refer to the applicable Operation and Service manual for that System IIA instrument.

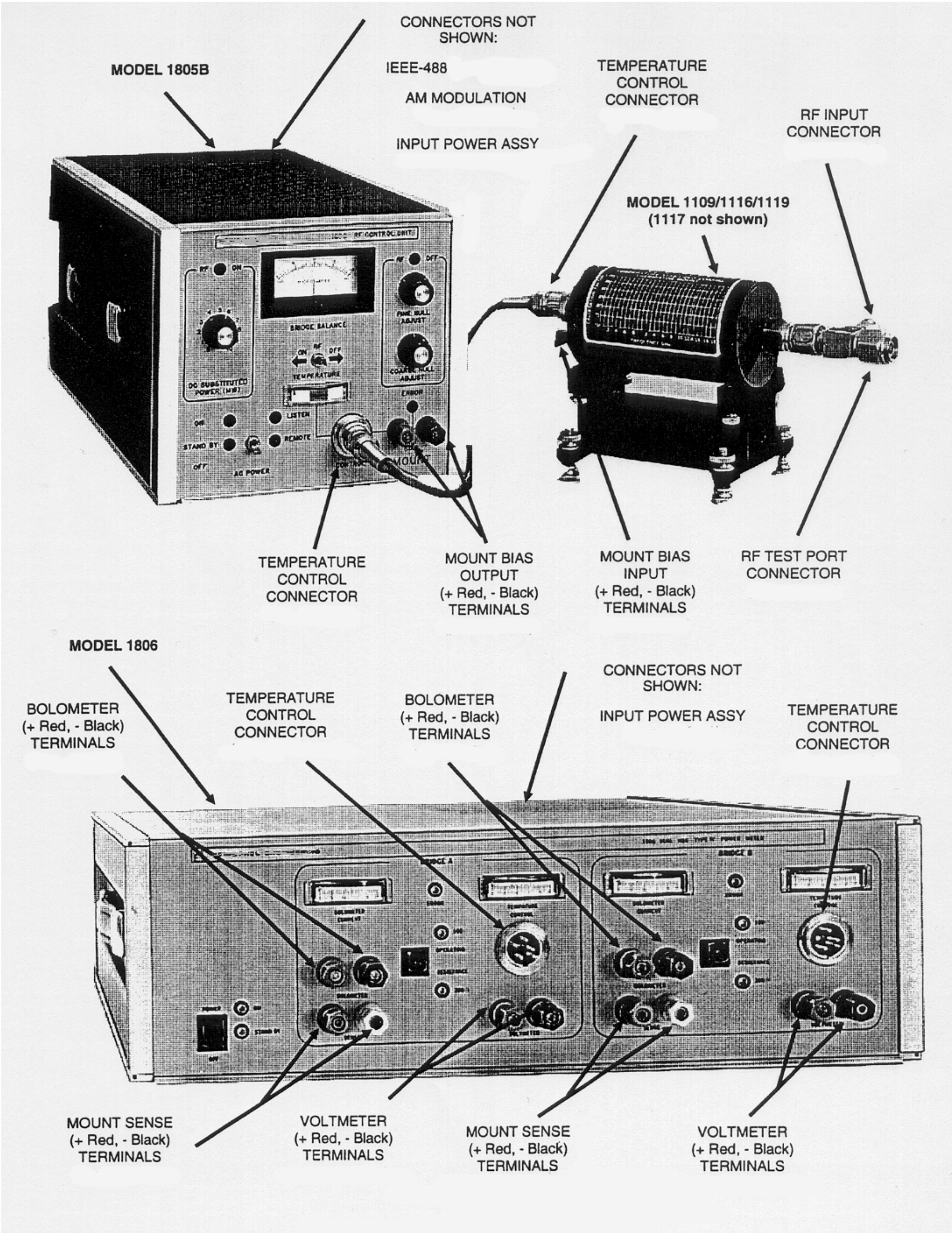


Figure 2-1 INPUT/OUTPUT Options

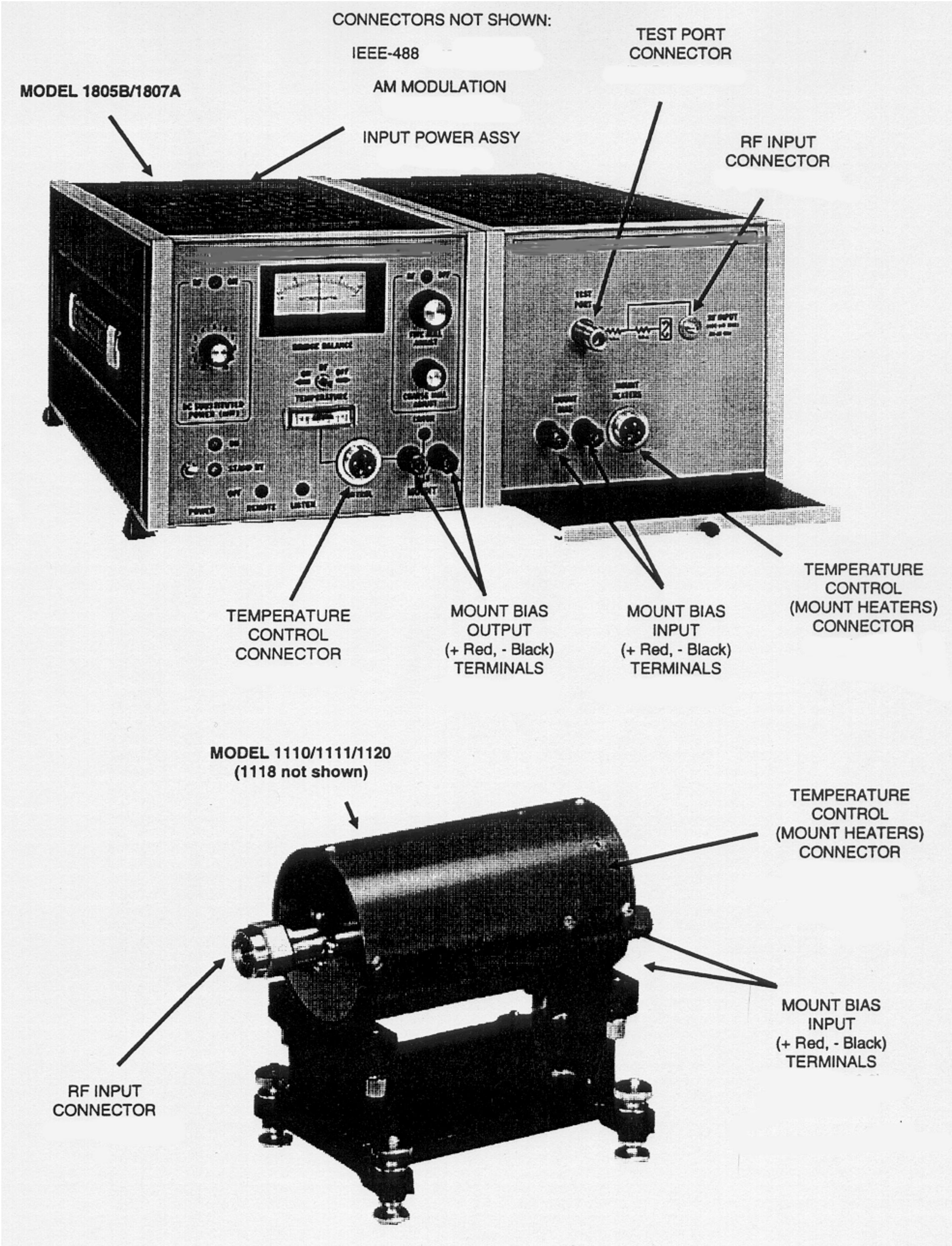


Figure 2-2 INPUT/OUTPUT Options

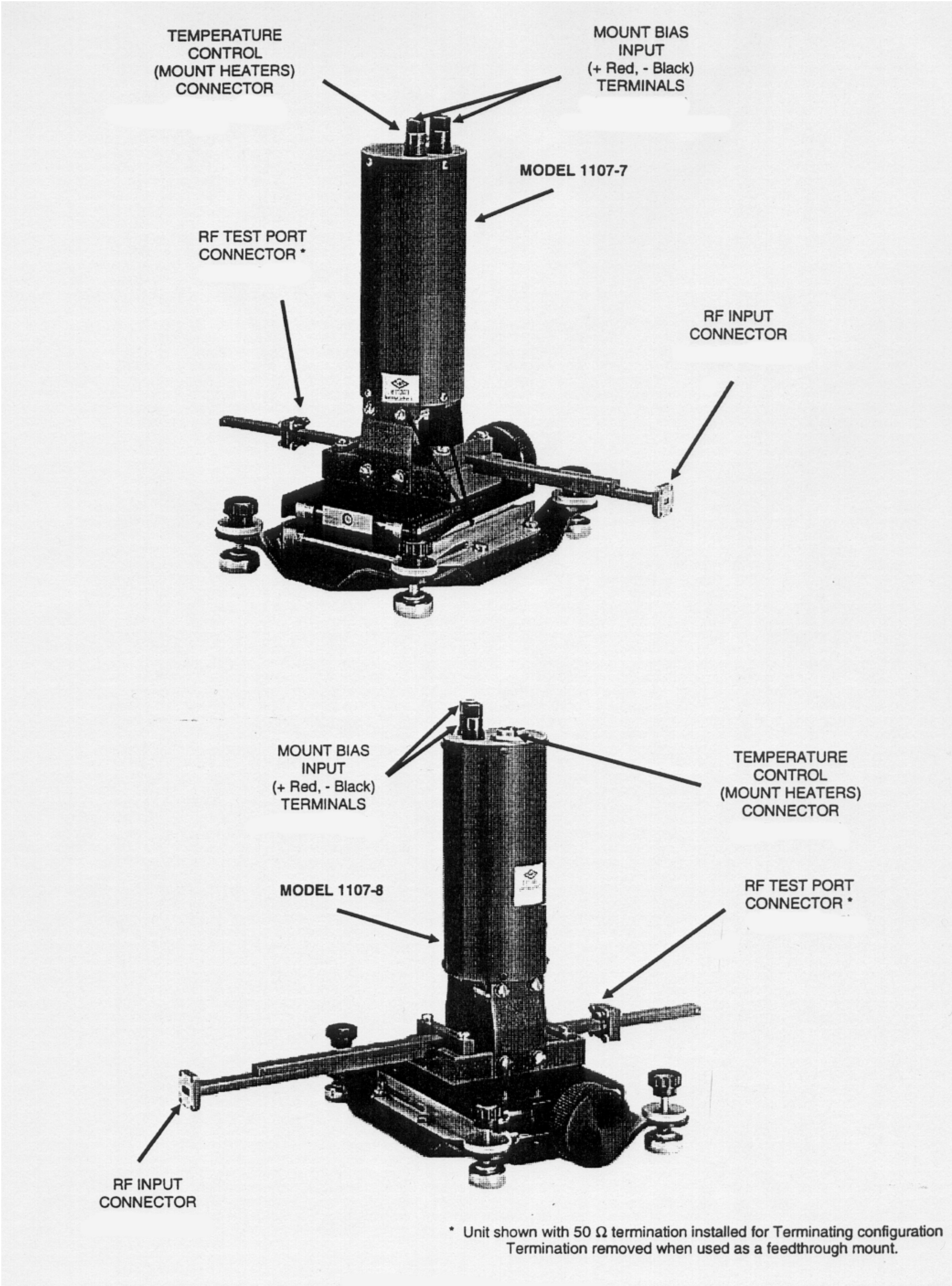


Figure 2-3 INPUT/OUTPUT Options

AM Modulation Connector

This BNC female connector is located on the upper left corner of the Model 1805B rear panel and is used as part of the leveling loop for the precision Power Source.

WARNING

Sufficient power levels are present at each instrument Power Input Assembly to cause personal injury. Ensure that all instrument power cords are DISCONNECTED before attempting to change any fuses.

Power Input Assembly

Each instrument Power Input Assembly contains a three-prong ac power input connector and a voltage selector assembly. The design of the Power Input Assembly prevents access to the Voltage Selector drum or the Fuse Assembly while an ac power cord is connected to the instrument. This design is not to be modified.

The Voltage Selector/Fuse Assembly reconfigures the instruments to different operating voltages. Each assembly contains a line voltage fuse and voltage selector. Refer to the applicable instrument O & S Manual for replacement of the fuse and/or proper alignment of the voltage selector to change the operational power requirements to either 100, 120, 220, or 240 Vac.

The AC Power Connector is a plug-type, prong insert connector with three conductors for connection of the power cord (P/N 068-21) to the Power Supply Assembly located within each instrument. This connector also grounds the chassis of the instrument when the AC power cord is connected to a grounded wall outlet. If necessary, use a three prong to two-prong adapter and connect the adapter's ground lead to the outlet plate retaining screw.

CONNECTING RF SIGNAL SOURCES TO SYSTEM IIA

Figures 2-4 through 2-8 provide interconnection diagrams for System IIA compatible signal generators when used with the Precision Power Source (Model 1805B).

CONNECTING THE SYSTEM IIA

Figures 2-9 through 2-12 provide interconnection diagrams for the System IIA as follows:

Figure 2-9	Precision Power Source using a Model 1805B RF Control Unit, Model 4380 Synthesized CW Signal Source, and Model 1109, 1116, 1117 or 1119 Feedthrough Mount.
Figure 2-10	Precision Power Meter using a Model 1805B RF Control Unit, Model 4380 Synthesized CW Signal Source, and Model 1807A RF Transfer Standard
Figure 2-11	Precision Power Meter using a Model 1806 Type IV Power Meter, Model 8505 Digital Voltmeter, and Model 1110, 1116, 1118 or 1120 Terminating Mount.
Figure 2-12	Precision Through Power Meter using a Model 1806 Type IV Power Meter, Model 8505 Digital Voltmeter, and Model 1107-7 or 1107-8 Waveguide Standard.

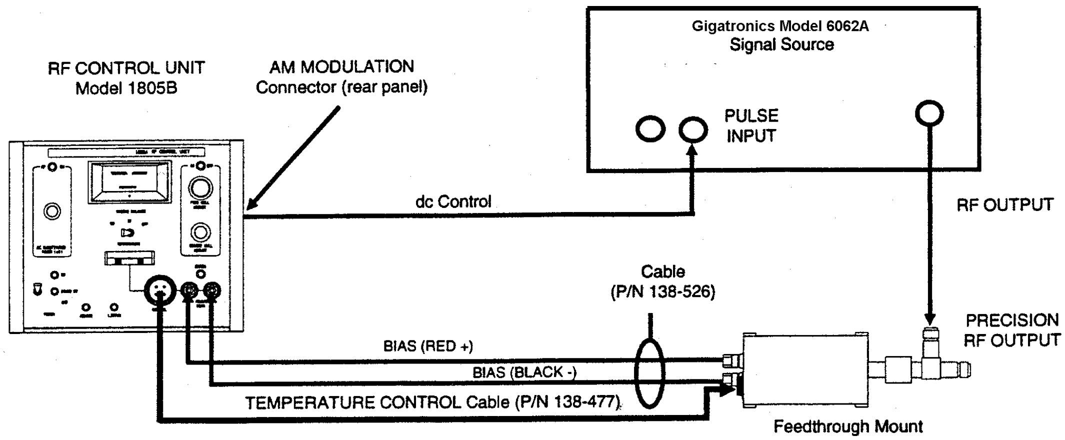


Figure 2-4 Connect Diagram Using Gigatronics 6062A

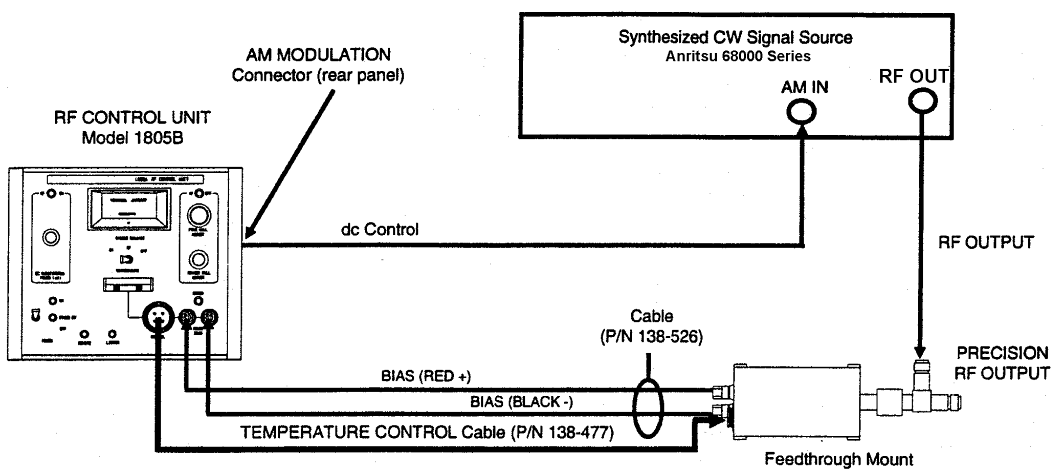


Figure 2-5 Connection Diagram Using Anritsu 68000 Series

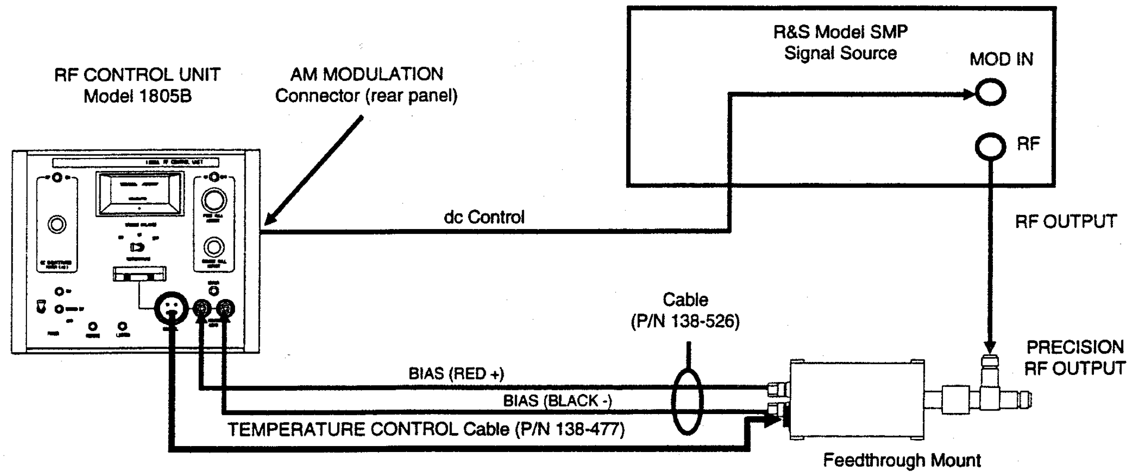


Figure 2-6 Connection Diagram Using R&S SMP

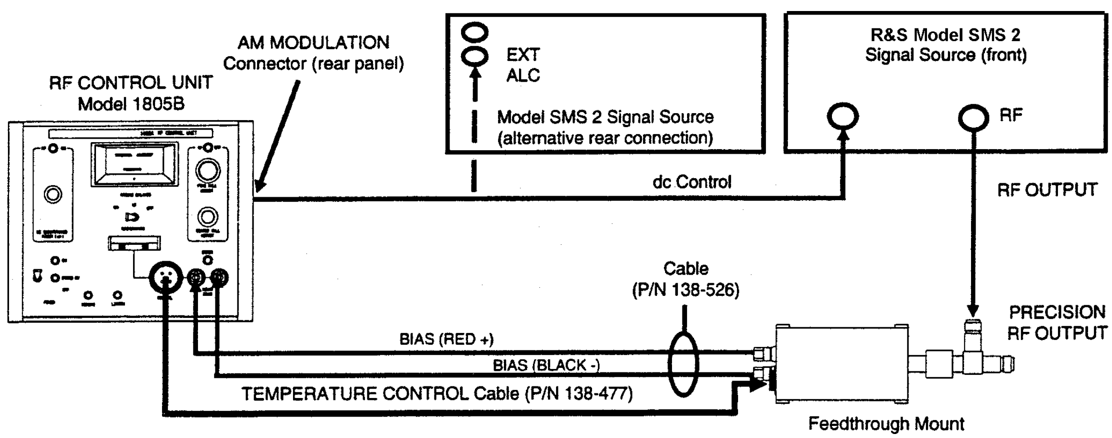


Figure 2-7 Connection Diagram Using R&S SMS2

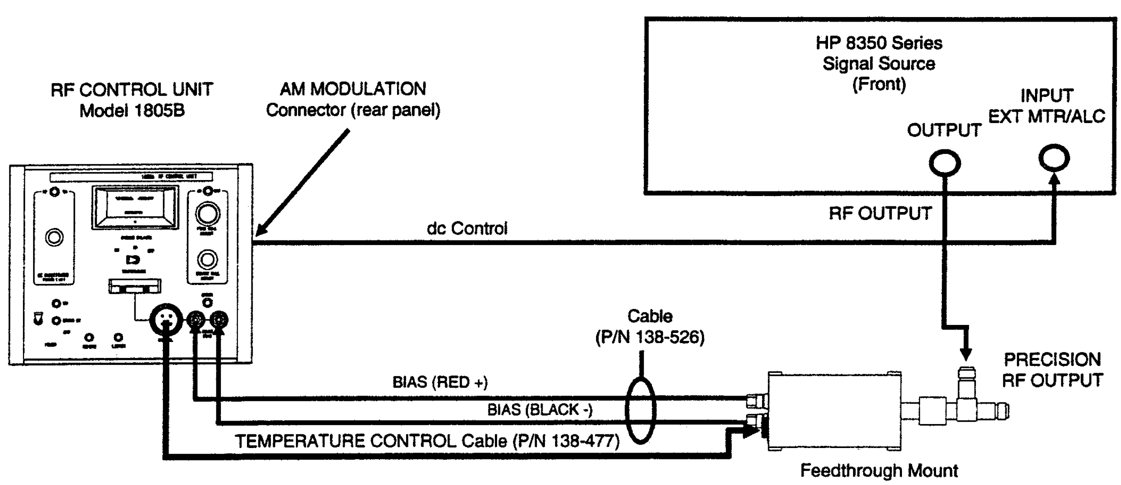


Figure 2-8 Connection Diagram Using HP 8350 Series

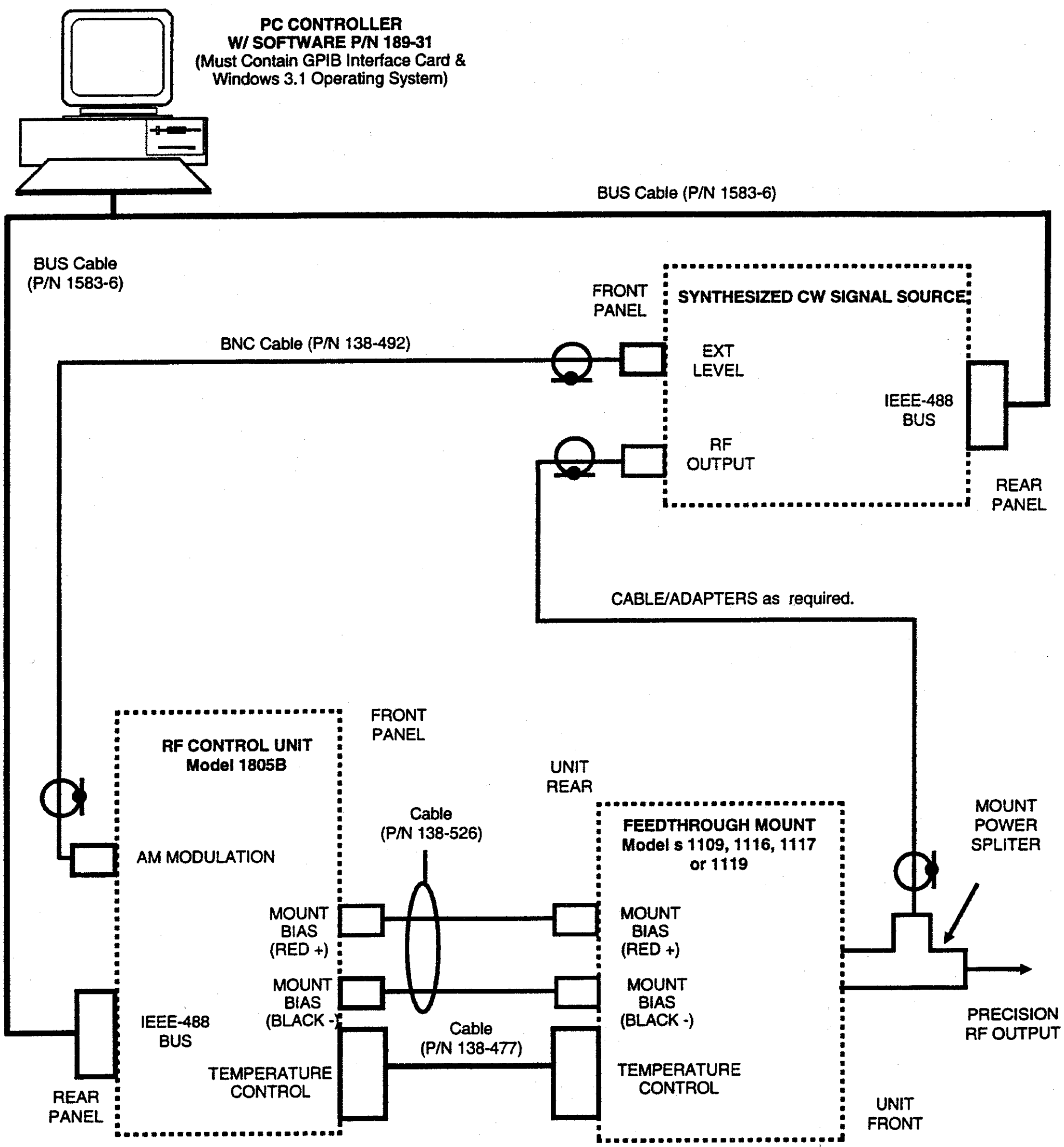


Figure 2-9 Precision Power Source Setup

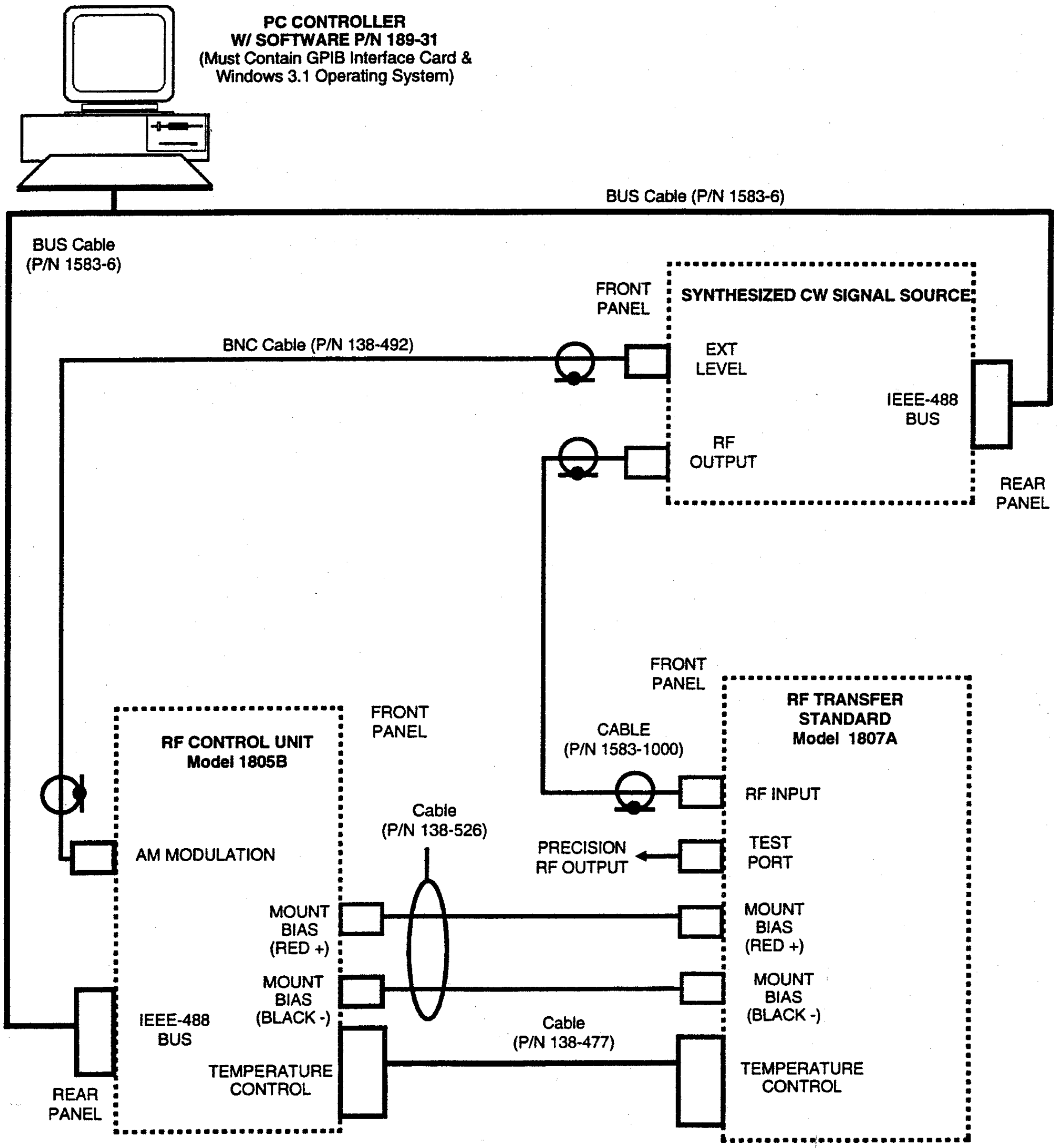


Figure 2-10 Precision Power Source Setup

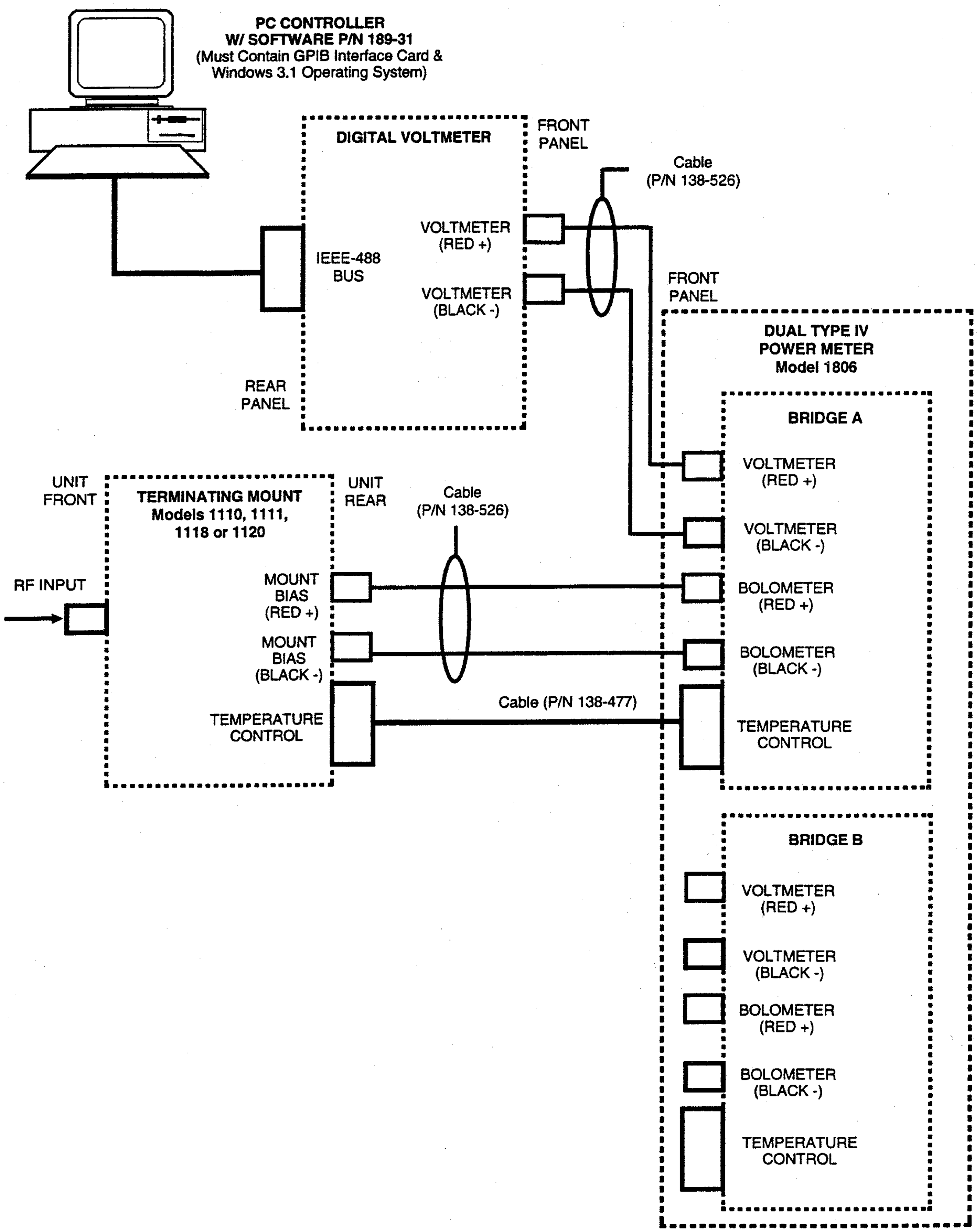


Figure 2-11 Precision Power Meter Setup

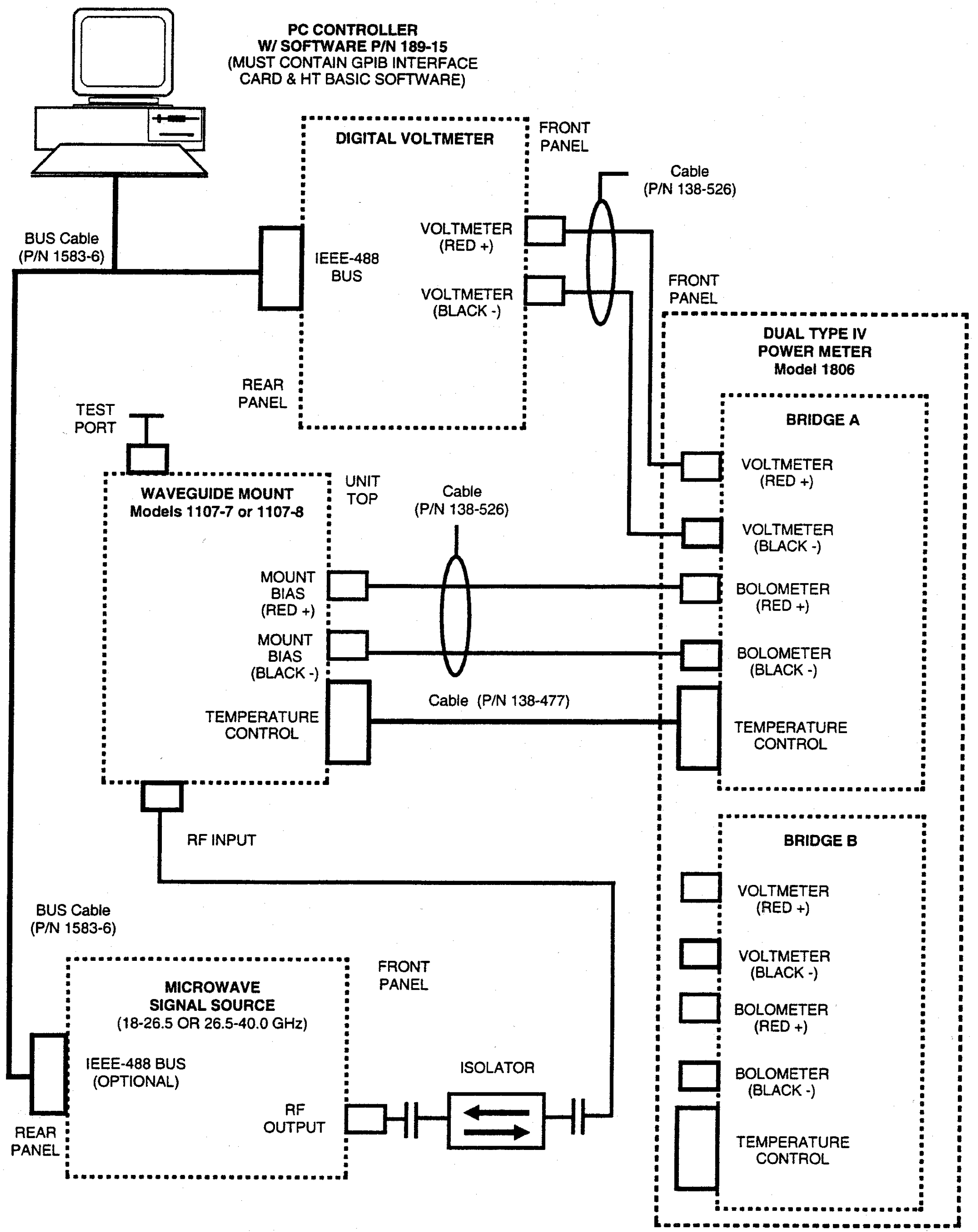


Figure 2-12 Precision Through Meter Setup

PREPARATION FOR RESHIPMENT OR STORAGE

RESHIPMENT

Perform the following procedure when reshipping an instrument or component to TEGAM.

NOTE

- DO NOT return any instrument or component to TEGAM without receiving prior factory authorization. Contact the Sales Department at TEGAM for a Return Material Authorization (RMA) number.
- Use the best available packing materials to protect the instrument during reshipment. When possible, use original shipping container and packing materials.

a. Cover the front panel connectors with plastic connector covers.
b. Wrap instrument with sturdy paper or plastic.
c. Place all accessories, cables and loose hardware into a plastic bag.
d. Place the wrapped instrument into a strong container with a layer of shock absorbing material wrapped around all sides of the instrument to provide a firm cushion and to prevent movement inside the container.
e. Place bag of accessories and hardware into container.
f. If shipping the instrument for service, attach a tag to indicate the following:

- Model and serial number
- Service required
- Description of malfunction
- Return address
- Authorization to conduct repairs
- Instrument repair authorization (RMA Number)
- Name and Phone Number of Technical Contact

g. Thoroughly seal shipping container and mark it FRAGILE.
h. Ship to an authorized sales representative or:

TEGAM, Inc.
10 TEGAM Way
Geneva, OH 44041
USA

STORAGE

When the System IIA instruments are to be stored for extended periods, pack instrument into a container. Place container into a clean, dry, temperature-controlled location. If instrument is to be stored in excess of 90 days, place desiccant with items before sealing container. The safe environmental limits for storage are as follows:

Temperature:	-40° to +167°F (-40° to +75°C)
Humidity:	less than 95%
Altitude:	less than 40,000’ (12,192 m)

SECTION III THEORY & OPERATION

GENERAL

This section contains theory and operating instructions necessary to perform power measurements and calibrations using the System IIA Automatic Power Meter Calibration System. Also this section includes:

- A discussion of DC Substitution and its relationship with the System IIA.
- Descriptions of all equipment used in and with the System IIA.
- Descriptions of all controls and indicators located on the instruments and instructions to operate the different configurations of the System IIA.
- A discussion of the different subsystems and setups of the System IIA, such as the Precision RF Power Source, Precision Through Power Meter, and Precision Power Meter.
- Procedures to set up and calibrate different types of Power Sensors using the System IIA.
- A listing of some of the different Power Sensors calibrated by the System IIA. This list also includes the standards recommended to calibrate a particular Power Sensor.
- Discussions covering the System IIA's measurement and mismatch uncertainties, instrument errors, and calculating the Model 1806 Accuracy.
- A theoretical discussion covering the method of correcting for refection coefficient errors.
- TEGAM and NIST Traceability.

DC SUBSTITUTION AND SYSTEM IIA

DC Substitution is the basis from which System IIA derives its stability, accuracy and traceability. The principle of this technique is that a dc bias current heats a temperature sensitive resistor or bolometer such that its resistance reaches a certain predetermined value. RF power then incident on the resistor will heat it more such that the resistance will tend to change. However, the dc bias is provided by a bridge, which acts to maintain the value of the resistance at the predetermined level. The result then is that the dc bias current automatically decreases in direct proportion to the increase in incident RF power.

The dc bias applied to the bolometer can be measured very accurately using dc and resistance standards. Thus, the change in bias can also be measured very accurately.

The resistor or bolometer element is mounted in a microwave structure to obtain the best possible impedance match. If the match was perfect, then the change in dc bias would exactly equal the incident RF power. In practice, this is not the case. Therefore, the microwave structure or power standard has to be characterized and given a calibration factor.

For the terminating mount, this factor is denoted by K_1, and is defined as:

$$K_1 = \frac{P_{dc}}{P_{RF}}$$

where, P_{dc} is the change in dc bias power caused by the incident RF energy, and P_{RF} is the value of the incident RF power.

The K_1 calibration factors vary with frequency, and can be provided directly by NIST. (NIST also provides a second factor called "effective efficiency." This is defined as the ratio of the change in bias power, divided by the RF power actually dissipated in the power standard. The value of RF power used here is P_{RF} from the above equation minus the power reflected from the mount. This factor is normally much closer to 1.000, and accounts for the power dissipated within the microwave structure of the mount as opposed to that dissipated in the resistor or bolometer).

TEGAM coaxial power standards work at a nominal RF impedance of 50 Ohms. This is achieved by having two closely matched thermistor beads biased to reach 100 Ohms each, and connected RF-wise in parallel. From a dc point of view, however, they are connected in series giving the standards a 200-Ohm operating resistance.

DESCRIPTION OF EQUIPMENT

Calibration of RF power meter/sensor combinations is faster and more accurate than ever before when using the TEGAM System IIA. System IIA is IEEE-488 bus controlled and transforms a slow and costly task into a quick and accurate procedure.

The calibration accuracy of System IIA is typically less than 1% above accuracies provided directly by NIST, including mismatch uncertainties. Total accuracy is less than 1.2 to 2.5% (RSS) depending on frequency and VSWR of the device under test. Even this figure can be reduced by the use of certain correction techniques.

Calibration speed of the System IIA is typically 5 seconds per measurement frequency, depending on settling time of the power sensor/meter under test. System IIA is used for diode-type RF Power Meter sensor calibration as well as the transfer of calibration factors to thermistor and thermocouples. Accurate measurement of signal source output level can also be performed. Using power ratio methods, variable and step attenuators and attenuation measuring equipment can be calibrated as well as measurement of receiver, amplifier, or attenuator linearity. Other System IIA features include:

- Accuracies < 1% (RSS) above that provided directly by NIST
- 0.01to 18 GHz frequency range with 132 NIST traceable calibration points--expandable up to 40 GHz and down to 100 KHz
- Total system accuracy for the transfer of calibration factors 1.2% to 2.5% (RSS) in the 0.01 to 18 GHz range
- 5 seconds/measurement includes signal averaging and meter settling time
- Test Ports - N Male/Female, 7 mm or 3.5 mm
- Substituted power levels 0.5 mW and 1.0 mW to 10 mW in 1 mW steps ±0.1% + 1 μW (Typically, above 3 mW the Model 1727A is required to boost the power level from the source)
- Calibration factor transfer repeatability 0.1%

The following paragraphs provide a general description of each instrument or component supplied with the different configurations of the System IIA.

MODEL 1805B RF CONTROL UNIT

The 1805B RF Control Unit (Figure 3-1) provides fast, reliable, and accurate leveled RF power when used in a closed-loop feedback arrangement like the System IIA. The unit provides automatic dc substitution at 0.5 mW and 1 mW to 10 mW in 1 mW steps using local or IEEE-488 bus control for easy and accurate transfer of calibration factors.

When used with the Model 1109 RF Power Standard, the 1805B permits the accurate transfer of up to 132 calibration frequencies traceable to NIST from 0.01 to 18.0 GHz. The 1805B is also compatible with other TEGAM System IIA components including the Models 1116 and 1117 series RF Transfer Standards.

An internal temperature controller raises and maintains the temperature of the mount chamber above ambient. This minimizes the effects of changes in ambient temperature for all the RF Transfer Standards.

The Model 1805B operates in a closed loop configuration for leveling the RF output of compatible signal sources. They are controlled directly using an analog signal applied to a dc coupled AM input connector.

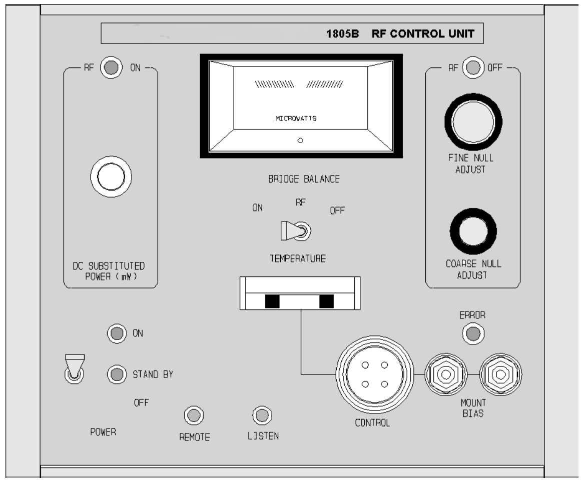


Figure 3-1 Model 1805B RF Control Unit

Ultra stable dc high precision metal film resistors provide dc power increments across a self-balancing bridge. The front panel bridge meter provides visual indication that closed loop stabilization has been achieved and enables rapid system operation. Coarse and fine adjustments are provided to obtain a meter null reading with no RF applied.

In addition to the bridge balance and temperature indicator, the Model 1805B contains several operational and performance checks. A front panel Mount Error indicator blinks if the voltage across the mount is not within a specified range. This alerts the operator of a mount fault such as open or shorted leads, or improper mount temperature. DC supply voltages are monitored by PC board mounted LEDs that illuminate with an active power supply. A standby mode switch allows mount heater circuit operation to maintain mount temperature at all times. This ensures full performance capability and long term stability of the bolometer mount (refer to IM-200 for more details about the Model 1805B).

MODEL 1806 TYPE IV POWER METER

The Model 1806 (Figure 3-2) is designed for use with bolometer elements to measure high frequency or microwave power. It also functions as a standard for the calibration of bolometer mounts, detectors, RF voltmeters, and for precision insertion loss measurements when used as part of the System IIA.

Figure 3-2 Model 1806 Type IV Power Meter

The exclusive use of 100% dc substituted power eliminates the effect of ac components on the bridge circuit which has been shown to introduce a substantial error in the substituted power due to the short-term time-constant of some bolometer elements. Substituted dc power levels ranging from 10 µW to 30 mW can be measured to within ± 0.03% + 2 µW with typical voltmeters which also makes this an ideal instrument for insertion loss measurements.

The 1806 contains two Type IV Power Meters and two built in temperature controllers for use with Thermistor/ Waveguide Mounts. The power meters are designed to bias either 100 or 200 ohm mounts and are thus compatible with SYSTEM IIA, the Model 1110, 1111, 1120 and 1107 Series RF Transfer Standards. A front panel switch selects operating resistance for each power meter. Each power meter has a bolometer current meter and fault LED indicator that illuminates under any condition preventing loop balance. Terminals are provided for an external DVM, positive and negative bolometer, and voltage sense (refer to IM-140 for more details about the Model 1806).

MODELS 1109, 1109H, 1116, 1117A, 1119 AND 1119H FEEDTHROUGH THERMISTOR MOUNTS

The TEGAM Models 1109 and 1116 (Figure 3-4, Model 1117A not shown) are Thermistor Mount Power Splitter combinations employed as feedthrough standards (K_2) in the System IIA Precision Power Source for the calibration of terminating power sensors such as terminating bolometer mounts and diode detectors and other terminating power meter sensors. Each unit is electrically sturdy, highly accurate, stable with time and temperature, and of sufficient quality for use as standards for the transfer of calibration factors to other standards and power meter sensors. The Model 1109 operates in the 0.01 to 18 GHz frequency range and is supplied with 132 calibration points which are traceable to NIST (refer to IM-128 for more details about the Model 1109). The Model 1116 operates in the 0.1 to 100 MHz frequency range and is supplied with 17 calibration points traceable to NIST (refer to IM-205 for more details about the Model 1116). The Model 1117 operates in the 0.05 to 26.5 GHz frequency range and is supplied with 137 calibration points traceable to NIST (refer to IM-245 for more details about the Model 1117). The Model 1119 operates in the 100 kHz to 4.2 GHz frequency range and is supplied with 76 calibration points traceable to NIST (refer to IM-240 for more details about the Model 1119). Model 1109H (0.01 to 18 GHz) and 1119H (100 kHz to 4.2 GHz) contain a 10 dB calibrated attenuator to allow the user to calibrate 100 mW sensors.

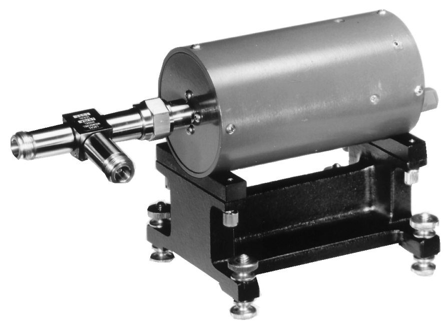


Figure 3-3 Models 1109, 1116 & 1119 (Feedthrough)

MODEL 1807A RF TRANSFER STANDARD

The TEGAM Model 1807A (Figure 3-5) is an RF transfer standard that supplies 140 calibration points which are traceable to NIST and Technology in the 0.01 to 18 GHz frequency range. The Model 1807A is an alternative to the 1109 Thermistor Mount which simplifies test configurations, reduces cable-derived errors, and provides damage protection for its internal thermistor mount (refer to IM-199 for more details about the Model 1807A).

Figure 3-4 Model 1807A RF Transfer Standard

MODELS 1110, 1111, 1118 AND 1120 TERMINATING THERMISTOR MOUNTS

The TEGAM Models 1110, 1111, 1118 and 1120 Coaxial Power Standards (Figure 3-6) are employed as terminating standards (K_1) in the System IIA Precision Power Source for the calibration of feedthrough devices such as through line RF power meters, bolometer mount-coupler and bolometer mount-splitter assemblies. These units are highly accurate, stable with time and temperature, and are used as standards for the transfer of calibration factors to other standards and power meters. The Model 1110 operates in the 0.01 to 18 GHz frequency range and is supplied with 132 calibration points which are traceable to NIST (refer to IM-128 for more details about the Model 1110). The Model 1111 operates in the 0.1 to 100 MHz frequency range and is supplied with 17 calibration points traceable to NIST (refer to IM-205 for more details about the Model 1111). The Model 1118 operates in the 0.05 to 26.5 GHz frequency range and is supplied with 137 calibration points which are traceable to NIST (refer to IM-245 for more details about the Model 1118). The Model 1120 operates in the 100 kHz to 4.2 GHz frequency range and is supplied with 76 calibration points traceable to NIST (refer to IM-240 for more details about the Model 1120).

Figure 3-5 Models 1110, 1111 & 1120 (Terminating)

MODELS 1107-7 (18 -26.5 GHz) AND 1107-8 (26.5-40 GHz) WAVEGUIDE TRANSFER STANDARDS

The TEGAM Models 1107-7 and 1107-8 (Figure 3-7) are waveguide power standards designed for precise measurements of microwave power in the 18 to 26.5 GHz and 26.5 to 40 GHz, respectively. Both units consist of a 3 dB coupler with a thermistor on the coupler's side arm and a termination on the coupler's main arm. With the termination removed, the unit becomes a feedthrough transfer standard for the transfer of calibration factors to terminating power standards or power sensors. With the termination attached, the unit is used as a terminating transfer standard. Ten calibration points traceable to NIST are provided for Model 1107-7 and 12 for Model 1107-8.

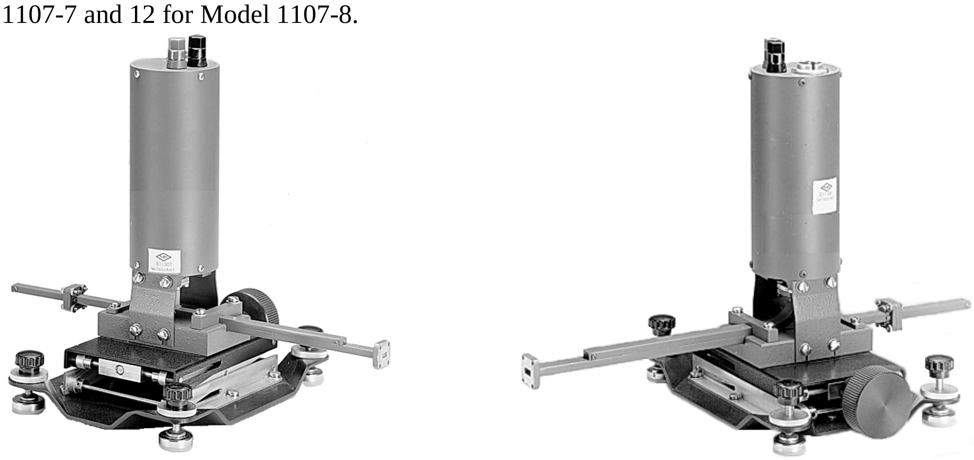


Figure 3-6 Waveguide Power Standards

MODEL 1727A RF AMPLIFIER

The Model 1727A Amplifier (Figure 3-7) is an accessory for use with the TEGAM System IIA Automatic Power Meter Calibration System. In a typical System IIA configuration, the 1727A can be used in conjunction with an RF generator to increase the overall output of the System IIA precision power source subsystem. The Model 1727A RF Amplifier provides the capability for automated switching between two generators providing output coverage from 100 KHz to 26.5 GHz at a single port. A variable gain amplifier on the 100 KHz to 10 MHz input provides level control when used with a TEGAM Model 1805B RF Level Control Unit in a System IIA Lowband configuration. This allows the use of low frequency generators having no external means of level control.

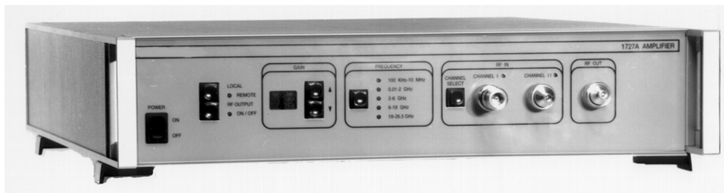


Figure 3-7 Model 1727A RF Amplifier

The instruments also contain amplifiers that can be switched in automatically providing output levels over the frequency range from 100 KHz to 18 GHz in excess of +26 dBm. This insures adequate power for calibration levels at the Feedthrough Standard of 10 mW when used with the Models1109H and 1119H. Additional amplification over the 18 to 26.5 GHz range provides a power boost to ensure at least 1 mW when used with the Model 1117A. The RF Amplifier functions are controlled over IEEE-488 bus using the System IIA Software program and a system controller.

SYSTEM SOFTWARE

The TEGAM System IIA SCAL software (P/N 189-31) operates in the Microsoft Windows environment on IBM compatible PC's. SCAL has been specifically designed for use with the TEGAM System IIA. The SCAL program significantly enhances the operation of the TEGAM System IIA by providing the technician with automated calibrations, data collection, data display and analysis capability. The capability to save and recall complicated system instrumentation and test configurations coupled with the graphical environment of windows makes SCAL easy to use by any level of personnel. When properly configured, the software will operate and control all system instrumentation to perform automated calibration and transfer of cal factors for the most commonly used power sensors and power meters. It also allows the direct transfer and storage of calibration factors from the Standard mount to feedthrough working standard thermistor mounts. Both analog and digital power meters can be calibrated with or without the IEEE bus options. Typically, a 10 MHz to 18 GHz power sensor can be calibrated at all 132 standard NIST calibration frequencies in less than 5 minutes.

This program allows for the manipulation and storage of the data files used during a calibration. Existing data files may be viewed, listed or modified and new data files can be created including data files for adapters and attenuators. Complex reflection coefficients can be stored for both the calibrator and the unit under test, so the user can correct for mismatch uncertainties. The software will do data averaging of up to 10 calibration runs and give the standard deviation. During the calibration process, the data is plotted in real-time in a graph window with the measured parameter plotted vs. frequency and numerically displayed in a spreadsheet style window. Multiple data files may be recalled and displayed side by side for comparison of past data.

COMPATIBLE RF SIGNAL SOURCES

The SCAL program supplies a wide variety of RF Signal Sources. Compatible RF Signal Sources include:

- Hewlett Packard 8340, 8350, 8360 & 8375
- Rohde & Schwarz SMX
- Rohde & Schwarz (Polarad) SMS-2
- Wiltron 6600, 6700 & 6800 Series
- Gigatronics/Fluke 6062A
- Gigatronics GT9000 Series

COMPATIBLE POWER METERS

The SCAL program allows the user to select from a wide variety of Power Meters. Compatible Power Meters include:

- Hewlett Packard 436, 437, & 438
- General Microwave 475
- Boonton 4200, 4220, & 4300 Series
- Gigatronics/WaveTek 8540 & 8542

COMPATIBLE VOLTMETERS

When calibrating a thermistor mount (TEGAM Model 1109 or 1110), or when calibrating a power meter without an IEEE 488 interface bus option, it is necessary to use a bus-controlled digital voltmeter. Compatible voltmeters include:

- Fluke 8502, 8505A, & 8506A
- Hewlett Packard 3455, 3458 & 3478
- Datron 1062 & 1271

COMPATIBLE BUS CONTROLLERS

A 486 or pentium-based computer with version 3.1 or 3.1.1 of Microsoft Windows™. An EGA, VGA, SVGA, or Hercules graphics card compatible with version 3.1 of Microsoft Windows™. A hard disk drive. At least 16 megabytes of Random Access memory (RAM). National Instruments GPIB-PCII/IIA IEEE 488 card, National Instruments PN776092-01 Rev. E of higher with the National Instruments Windows driver software Rev. 2.1.1 or higher installed on the PC. A pointing device such as a Windows compatible mouse or trackball. Performance and measurement speed will be somewhat dependent on the capabilities of the host system.

COMPATIBLE PRINTERS

SCAL makes use of the Windows printer functions to select and set up each printer to meet the specific needs of the user. Windows is supplied with many printer drivers, but not all are covered. In this case, the user should consult the printer manufacturer for Windows drivers specific to your make and model of printer. Make note that each printer driver will display a different dialog box within Windows to show the options specific to the printer-driver installed.

CONTROLS AND INDICATORS

The following paragraphs provide a description of all the controls and indicators located on the front panels of the Models 1805B and the 1806 that are associated with the System IIA. Figure 3-8 shows the location of all the switches and indicators on the front panels of Models 1805B and 1806. For switches or indicator not listed or more information about the controls and indicator listed, refer to the applicable Operation and Service Manual for each instrument.

LISTEN INDICATOR

The LISTEN indicator is a red LED located in the bottom center of the Model 1805B front panel. This indicator is only illuminated when the Model 1805B is addressed as a listener via the IEEE-488 bus.

REMOTE INDICATOR

The REMOTE indicator is a red LED located in the bottom center of the Model 1805B front panel. This indicator is only illuminated when the Model 1805B is under IEEE-488 bus control.

STANDBY INDICATOR

The STANDBY indicator is an amber LED located near the lower left-hand corner of the Model 1805B front panel. When the POWER switch is toggled to the STANDBY position (middle position), this Indicator illuminates, indicating that +30V power has been applied to allow pre-heating of the precision resistor network within the Model 1805B, and that the +20V temperature controller circuit for the thermistor mount has been activated.

WARNING

Ensure that input connector and voltage selector/fuse assembly is set for the proper voltage before switching the POWER Switch to ON or STANDBY; otherwise, damage may result to internal circuitry.

POWER SWITCH

The POWER switch is a three- (3) position toggle switch located near the lower left-hand corner of the front panel. In the down or OFF position, all power is removed from the Model 1805B internal and controlled external circuitry. In the middle or STANDBY position, +30V is applied for pre-heating the internal precision resistor network, +20V is applied to the temperature controller circuit for pre-heating the thermistor mount, and the amber STANDBY indicator is illuminated. In the up or ON position, all required power for operation is applied to the Model 1805B, and the green ON indicator is illuminated.

ON INDICATOR

The ON indicator is a green LED located near the lower left-hand corner of the Model 1805B front panel. When the POWER switch is toggled to the ON position, this indicator illuminates to indicate that all Model 1805B internal power supplies have been activated.

DC SUBSTITUTED POWER SWITCH

The DC SUBSTITUTED POWER switch is an eleven (11) position limited-rotation rotary switch located in the left-hand center of the Model 1805B front panel. When the Model 1805B is under manual control, this switch controls the level of the dc-substituted power being supplied. The selectable levels are 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 milliwatts. Under IEEE-488 bus control, this switch is inactive.

RF ON INDICATOR

The RF ON indicator is a green LED located in the upper left-hand corner of the Model 1805B front panel. When the RF ON/OFF switch is toggled to the left (ON) position, this indicator illuminates, indicating that the selected dc substituted power level is supplied to the bridge, and the appropriate RF control signals are routed from the rear panel of the Model 1805B. If the Model 1805B is under remote IEEE-488 bus control, this indicator illuminates when the RF ON functions have been performed by the software and system controller.

BRIDGE BALANCE METER

The BRIDGE BALANCE meter is located at the top center of the Model 1805B front panel, and is scaled from a low of -10 microwatts to a high of +10 microwatts relative to a mid-meter scale reference of zero (0). A 0 reference level reading on the meter indicates that the level controlled by the Model 1805B corresponds exactly to the dc substituted power level selected on the DC SUBSTITUTED POWER switch. Any deviation from the selected level is read on the meter as a low or high indication in microwatts. In operation, COARSE NULL ADJUST control and FINE NULL ADJUST control are adjusted to achieve a 0 or "null" reading on M1 prior to application of RF power. After applying RF power (either manually via the RF ON/OFF switch or automatically via the IEEE-488 control bus) the meter should, after a momentary deviation, again achieve a null reading to indicate that the Model 1805B has "locked on" to the RF source and is applying the proper amount of dc substituted power for calibration purposes.

RF OFF INDICATOR

The RF OFF indicator is a green LED located in the upper right-hand corner of the Model 1805B front panel. When RF ON/OFF switch is toggled to the right (OFF) position, this indicator illuminates, indicating that 30 mW dc power is supplied to the mount, and the appropriate RF control signal is routed to the rear panel. If the 1805B is under remote IEEE-488 bus control, DS1 illuminates when the functions of RF OFF (0) have been performed by the automatic system controller.

FINE NULL ADJUST CONTROL

The FINE NULL ADJUST control is a continuously-variable, knob-controlled potentiometer located near the upper right-hand corner of the Model 1805B front panel. This control provides a fine adjustment of the bridge balance reading on BRIDGE BALANCE meter prior to application of RF power.

COARSE NULL ADJUST CONTROL

The COARSE NULL ADJUST control is a continuously-variable, knob-controlled potentiometer located in the right-hand center portion of the Model 1805B front panel. This control provides coarse null adjustment of the bridge balance reading on the BRIDGE BALANCE meter prior to the application of RF power.

ERROR INDICATOR

The ERROR indicator is a red LED located near the lower right-hand corner of the Model 1805B front panel. This indicator is active only when RF power is NOT applied, and when illuminated, indicates either an open circuit (hookup or thermistor), or failure of the bridge to balance at 30 ±1 mW.

RF ON/OFF SWITCH

The RF ON/OFF switch (S2) is a two-position toggle switch located near the center of the front panel. During manual operation, placing this switch in the left (ON) position applies RF power, activates the 1805B circuitry to subtract the chosen dc substitution power from the thermistor elements in the mount, deactivates the RF OFF indicator and activates the RF ON indicator. During remote IEEE-488 bus controlled operation, this switch is left in the OFF position and the automatic system controller performs its function.

TEMPERATURE METER

The TEMPERATURE meter is located in the lower center of the Model 1805B front panel, and provides a dc voltage analog reading of temperature and temperature stability within the thermistor chamber. A green band on the meter scale provides a visual indication of normal operating temperature limits. Although some mounts may cause the meter to indicate above or below this green band, this does not affect the normal operation of Model 1805B, if the ERROR is not illuminated and the needle is stable and does not drift or vibrate erratically.

BOLOMETER CURRENT METER

The Bolometer Current Meter is in the upper left-hand corner of both Bridge A and Bridge B of the Model 1806 front panel. This meter measures, with a resolution of 1 mA, the thermistor bias current level applied through the Model 1806 Bolometer Mount Bias Connectors.

TEMPERATURE CONTROL METER

The Temperature Control Meter is in the upper-right-hand corner of both Bridge A and Bridge B of the Model 1806 front panel. This meter indicates a dc voltage level that is proportional to the current applied through Temperature Control Connector to a heater bridge in the thermistor mount. The green area on the meter indicates that the thermistor mount is in the correct temperature range. Although some mounts may cause the meter to indicate above or below this green band, this does not affect the normal operation of Model 1806, if the ERROR is not illuminated and the needle is stable and does not drift or vibrate erratically.

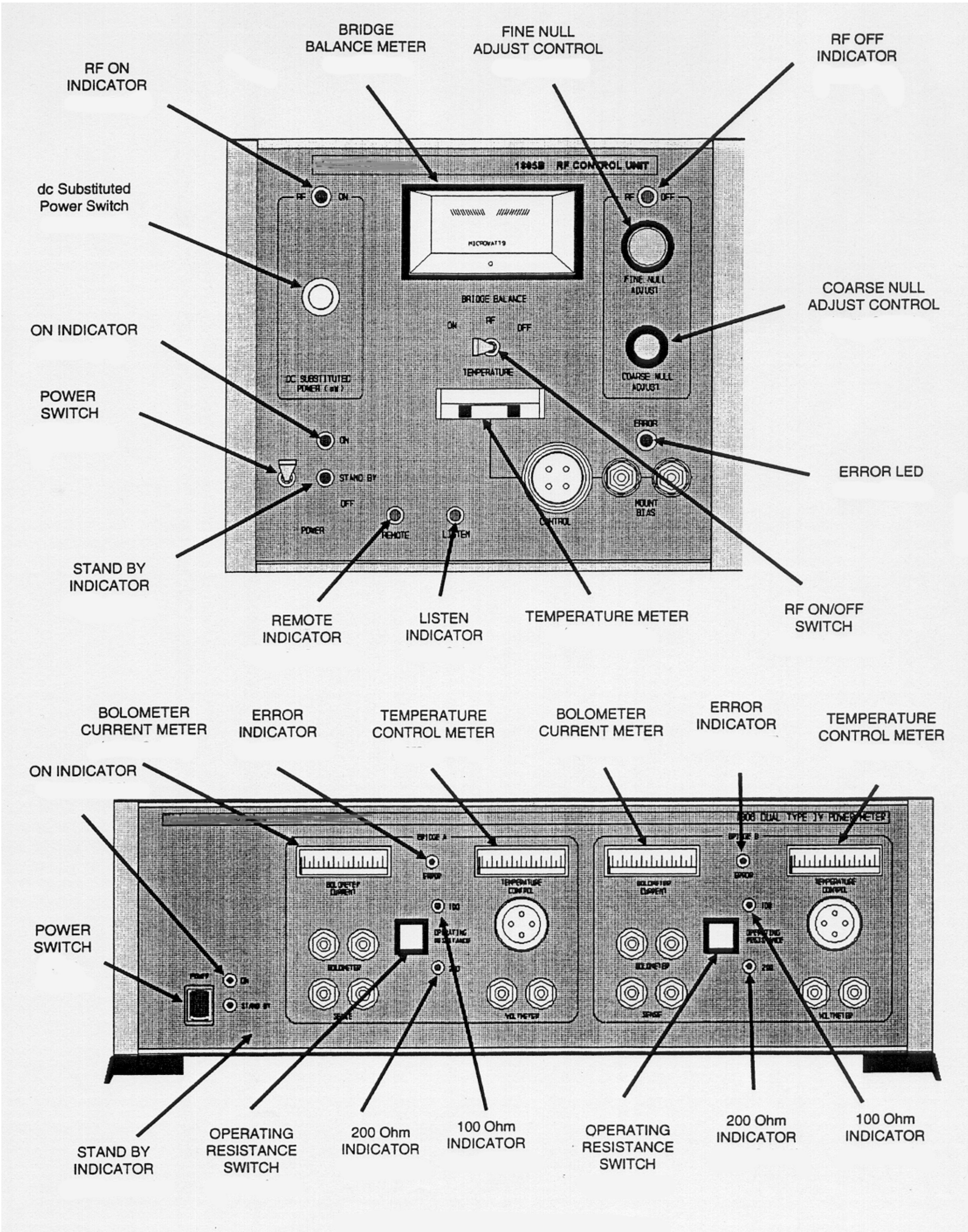


Figure 3-8 Controls and Indicators

ERROR INDICATOR

Each bridge on the Model 1806 contains one red indicator between Bolometer Current and Temperature Control Meters at the top of the bridge control panel. The ERROR indicator illuminates for any condition preventing the Type IV Bridge circuit from balancing.

100 OHM OPERATIONAL INDICATOR

Each bridge circuit on the Model 1806 contains a 100 ohm indicator in the center of the bridge control panel. This green indicator illuminates when the OPERATING RESISTANCE Switch sets the bridge circuitry for 100 Ohm operation.

200 OHM OPERATIONAL INDICATOR

Each bridge circuit on the Model 1806 also contains a 200 Ohm indicator below on the front panel. This green indicator illuminates when the OPERATING RESISTANCE Switch sets the bridge circuitry for 200 Ohm operation.

OPERATING RESISTANCE SWITCH

Each bridge on the Model 1806 contains a two-position, push- button OPERATING RESISTANCE Switch. The location of this switch is in the center of each bridge control panel. The position of the OPERATING RESISTANCE Switch configures individual bridge circuitry for either 100- or 200-ohm operation. Depending on the position of this switch, either the 100 ohm or 200 ohm operational indicator will be illuminated. When using a 100 ohm thermistor mount, set the switch to the in position for 100 ohm operation and to illuminate operational indicator for 100 ohm. When using a 200 ohm thermistor mount, set the switch to the out position for 200 ohm operation and to illuminate operational indicator for 200 ohm.

WARNING

Ensure that input connector and voltage selector/fuse assembly is set for the proper voltage before switching the POWER Switch to ON or STANDBY; otherwise, damage may result to internal circuitry.

POWER SWITCH

The Model 1806 POWER Switch controls operational power and is in the lower left-hand corner of the Model 1806 front panel next to the ON Indicator. This switch is a three-position toggle switch that completes, extends, or terminates power to the Model 1806. In the uppermost position, this switch extends power to the entire circuitry within the Model 1806 that enables all unit operations. In the middle position, this switch places the Model 1806 in a STANDBY mode for warm-up. STANDBY mode applies only necessary power to heat the Model 1806 and associated thermistor mounts. When switched to the lowest position, this switch terminates power to the Model 1806.

STANDBY INDICATOR

The STANDBY indicator location is just below the ON indicator in the lower left-hand corner of the Model 1806 front panel. This yellow indicator illuminates when the Model 1806 POWER Switch is in the STANDBY position and power is being applied to the unit. Illumination of this indicator indicates that partial power is supplied to the unit and test functions such as changing the bridge operating resistance or monitoring bridge bias are not available.

ON INDICATOR

The ON indicator is located in the lower left-hand corner of the Model 1806 front panel just to the right of the POWER Switch. This green indicator illuminates when the Model 1806

POWER Switch is in the ON position indicating supply of operational power to the unit and availability of all operations.

PRECISION POWER SOURCE

In the basic System IIA, the Models 1805B, and F1109, and a suitable generator are connected together to form a source of RF power that is extremely stable and repeatable, and can be known to within a tight tolerance. Figure 3-9 shows this arrangement.

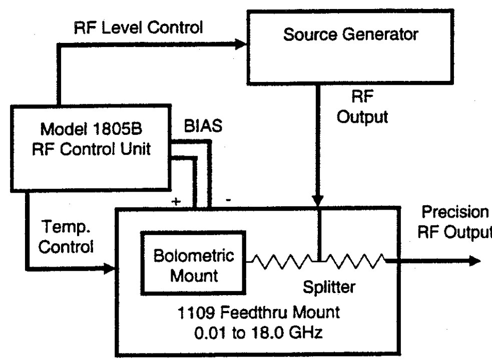


Figure 3-9 Precision RF Power Source

The Model 1805B provides the oven control for the thermistor mount of the Model 1109, plus the dc bias for the thermistors (bolometer elements) themselves. With the source RF power switched off, the 1805B is adjusted for bridge balance, at which point enough dc bias power is being dissipated in the thermistors to maintain them at an accurate 200 Ohms.

A dc substitution power level is chosen on the front panel of the 1805B (or over the IEEE-488 Bus). Values are 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 mW. When a value is chosen, the dc bias to the thermistor mount is reduced by that value. The bridge within the 1805B now detects an imbalance and provides an error signal, which is used to change the source level such that the incident RF coming into the thermistor mount replaces the heat lost by the dc bias reduction.

The Model 1109 Feedthrough Mount consists of a Model 1110 Terminating Mount connected to a power splitter (Refer to Figure 3-10). Since the mount, the Model 1805B and the source form a leveling loop, the center of the splitter is a constant voltage point. Thus, when a sensor is connected to the other port of the splitter, the loop maintains a constant voltage at the splitter center. Within the capabilities of the source, this voltage is independent of the loading on the splitter. Thus, the incident power available at the splitter output port is constant and independent of load.

Although the thermistor mount is inherently very stable and repeatable, it does not provide a perfect 50 Ohm match at RF frequencies. The splitter, although it has an excellent SWR at each port given a constant voltage at its center, is also not perfectly symmetrical. To overcome these imperfections, the thermistor mount and splitter are coupled together in a semi-permanent fashion, and the combination is given a calibration factor, usually denoted by K_2.

The Calibration Factor K_2 is defined by:

$$K_2 = \frac{P_{dc}}{P_{RF}}$$

where P_{dc} is the value of substituted dc bias selected on the front panel of the 1805B, and P_{RF} is the RF power available at the splitter output port, when the leveling loop is in balance.

K_2 varies with frequency, and is almost always less than 1.000. The RF power available at the output of the splitter, i.e., the output of the Feedthrough Mount, is always greater than the substituted dc bias selected. For example, if K_2 is 0.950 and 1 mW is selected, the RF power available is 1.053 mW, i.e.,

$$P_{RF} = \frac{P_{dc}}{K_2} = \frac{1mW}{0.950} = 1.053mW$$

Thus, although the available power is not necessarily very close to the selected substituted dc bias, its value is known very accurately.

The sensor to be calibrated is connected to an appropriate power meter. It is zeroed and set to read correctly, when attached to the reference level within the power meter. It is then connected to the output port of the Feedthrough Mount. The frequency is varied, and at each frequency the available power as calculated above is compared with the power meter reading. The ratio is the sensor calibration factor.

If K_{1S} is the calibration factor of the sensor, it is defined by:

$$K_{1S} = \frac{P_m}{P_{RF}}$$

where, P_m is the power as indicated by the power meter, and P_{RF} is the available power. This equation can also be written:

$$K_{1S} = \frac{P_m \text{ x } K_2}{P_{dc}}$$

where P_{dc} and K_2 are as defined above.

Although up to 10 mW of dc substituted bias is available at the 1805B, the limiting factor on available RF power is usually the source. The splitter in the feedthrough mount reduces available power by approximately 6 dB. Cable losses and the calibration factor mean that the source has to be capable of providing approximately 8 dB more than is selected. For 1 mW a source capability in excess of +8 dBm is usually adequate. This becomes +18 dBm for 10 mW. An extra amplifier is usually needed in this latter case.

The Model 1109 Feedthrough Mount is optimized to work from 10 MHz to 18 GHz. The Model 1116 has been optimized to work down to 100 KHz.

The Model 1109 is fitted with Type N connectors. However, if another connector type is needed, a precision adapter can be used. It must be characterized and its effect then taken into account. The same is true for high sensitivity sensors, which are calibrated with a 30 dB attenuator on the output of the Feedthrough Mount. The system software is capable of automatically pulling up this data from user selected files, and correcting for it.

In the procedure described above, the largest error source is due to mismatch. This will be discussed at length in a later section.

PRECISION THROUGH POWER METER

The precision power source shown in Figure 3-11 only functions to 18 GHz. This can be extended to 26.5 GHz using the F1117A Coaxial Feedthrough Mount. Above 18 GHz, the waveguide standards can be used, and provide calibration by functioning as through power meters.

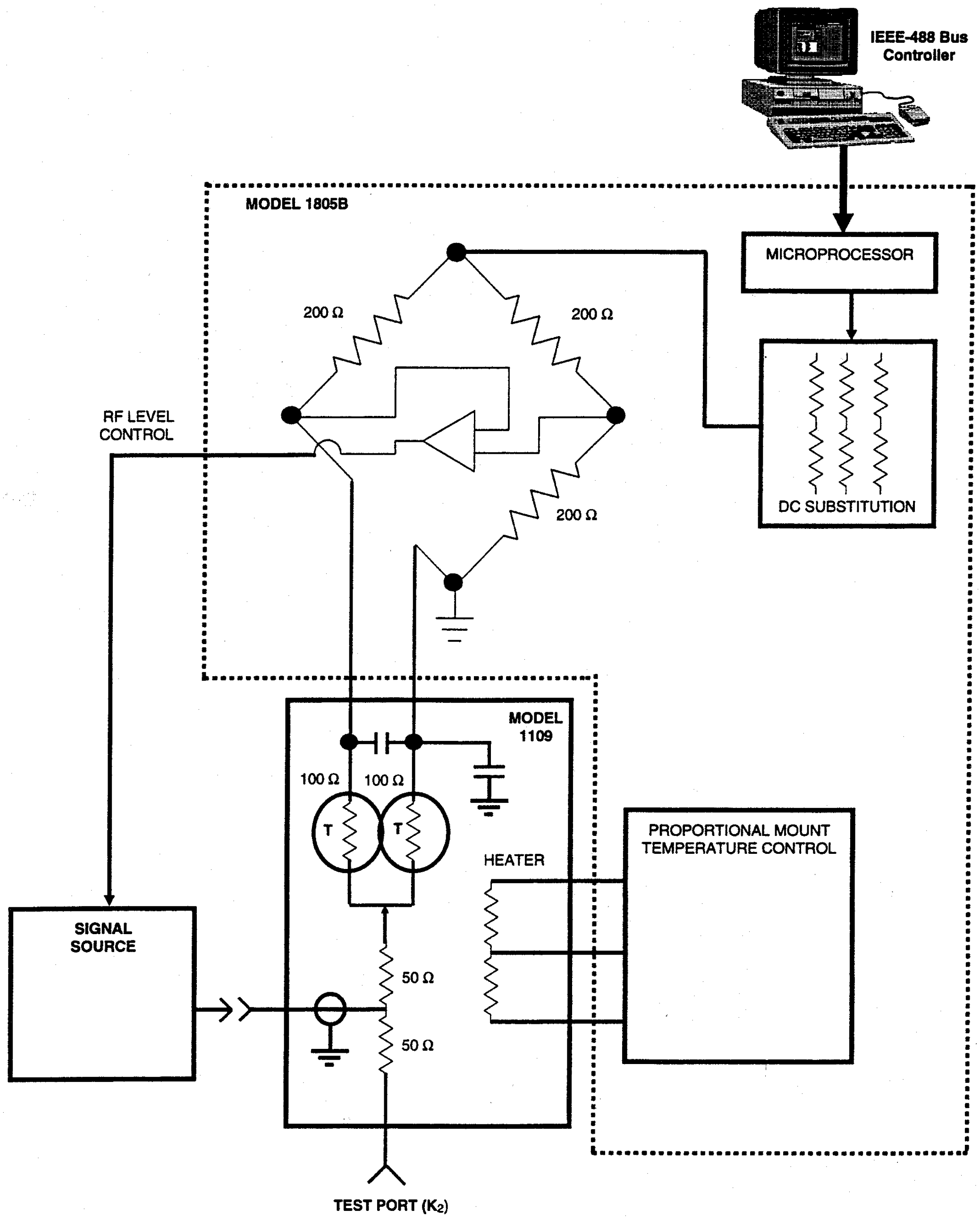


Figure 3-10 Precision Power Source Schematic

TEGAM has two waveguide power standards covering the ranges 18-26.5 GHz in WR42, and 26.5-40 GHz in WR28. These are the 1107-7 and 1107-8, respectively. They are constructed in somewhat similar fashion to the 1110 in that they have a thermistor bead in a stabilized oven, and work in identical fashion regarding the principle of DC substitution. The microwave structure is, however, in waveguide and they are attached to the side-arm of a 3 dB waveguide coupler. When used with a termination, they become a terminating standard, and this is used for traceability. This will be dealt with in a later section.

Figure 3-11 shows the waveguide through mount being used to calibrate a waveguide sensor.

Since the thermistor mount is permanently attached to a 3 dB waveguide coupler, only half the power fed to the through standard appears at the output. However, the through standard is given a set of calibration factors K_2, which are defined as follows:

$$K_2 = \frac{P_{dc}}{P_{RF}}$$

where P_{RF} is the actual power available at the output port of the standard, and P_{dc} is the dc substituted power as registered by the Model 1806 and the DVM.

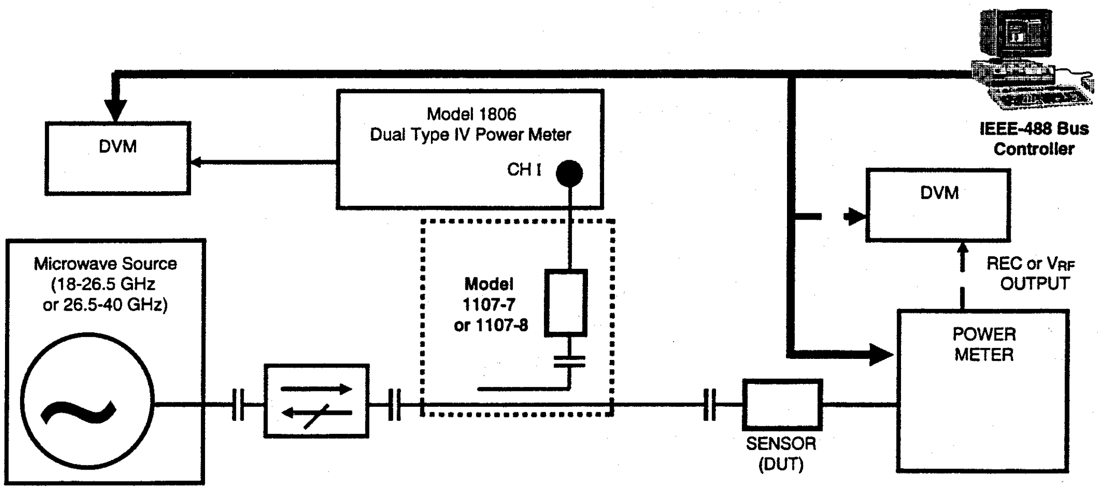


Figure 3-11 Precision Through Power Meter Setup

To calibrate a waveguide power sensor, it is first connected to the output of the standard, having been zeroed and initialized with its attached power meter. Its reading for the power level is then compared with the known available power and the ratio becomes its calibration factor. If K_{1S} is the calibration factor of the sensor being calibration then:

$$K_{1S} = \frac{P_m}{P_{RF}}$$

where P_m is the power as registered by the sensor and associated power meter, and P_{RF} is the available power as calculated above. Hence:

$$K_{1S} = \frac{P_m \times K_2}{P_{dc}}$$

where K_2 and P_{dc} are as defined above. (P_{dc} is calculated by measuring the voltage across an accurate 200 Ohm resistor, which, being part of a self-balancing bridge in the Model 1806, carries the same current as the thermistor beads (Figure 3-12). A voltage reading is made with no RF incident power. This yields a reference power given by:

$$P_{REFDC} = \frac{V_{RFOFF}^2}{200\Omega}$$

where V_{RFOFF} is the voltage reading across the resistor. When RF power is applied, the dc power needed to maintain the temperature and hence resistance of the thermistors becomes less. The self-balancing bridge corrects this and a new voltage reading is taken, V_{RFON}. The new power reading is given by:

$$P_{RFONDC} = \frac{V_{RFON}^2}{200\Omega}$$

and the dc substituted power is given by:

$$P_{dc} = P_{REFDC} - P_{RFONDC} = \frac{V_{RFOFF}^2 - V_{RFON}^2}{200\Omega}$$

(Refer to IM-200 for more information about the 1805B)

Although these standards are waveguide units, they can be used to calibrate coaxial sensors in those frequency ranges. A suitable waveguide to coaxial adapter is needed. It must first be characterized and the data used to correct the available power value.

High sensitivity sensors can likewise be calibrated using a suitable waveguide attenuator of approximately 30 dB attached to the output of the standard. It must first be characterized and the attenuation taken into account in calculating the available power to the sensor.

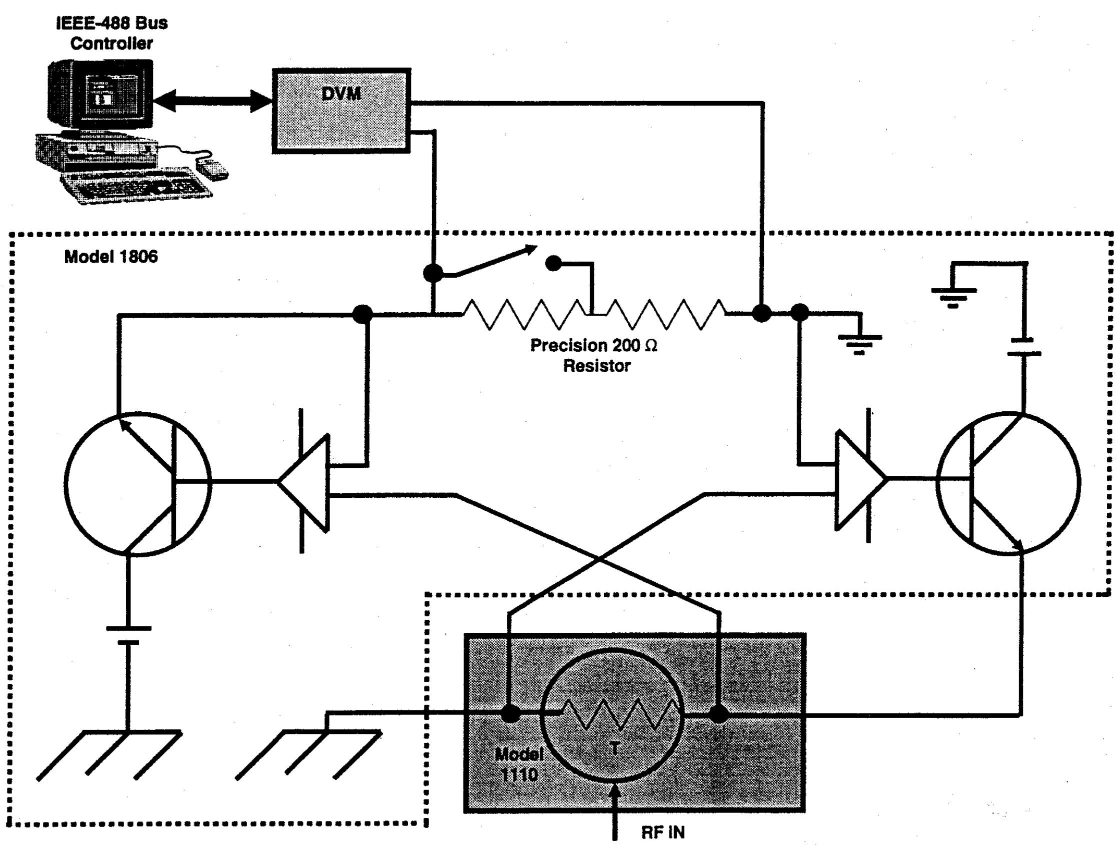


Figure 3-12 Precision Power Measurement Schematic

PRECISION POWER METER

The Model 1806, coupled with either an M1110, M1111, M1118, or M1120 terminating power standard, or with an 1107-7 or 1107-8 waveguide mount with attached termination, becomes a precision power meter. All of these standards are given a calibration factor K_1, where:

$$K_1 = \frac{P_{dc}}{P_{RF}}$$

where P_{dc} is the dc substituted power as registered by the change in voltage across the accurate 200 Ohm resistor in the 1806 Type IV bridge, and P_{RF} is the actual incident RF power (the previous section covers the mathematics behind the measurement of P_{dc}).

Because of the principle of dc substitution, and because of the proven stability of the thermistor beads, these mounts can all be given calibration factors directly by NIST at Boulder, Colorado, or by other Standards Laboratories around the world. This makes them useful for transferring calibration to the various feedthrough mounts mentioned in previous sections, a calibration that is directly traceable to the Standards Laboratory used. This transfer of calibration is, indeed, the paramount use of the Precision Power Meter in System IIA.

Figure 3-13 shows a typical calibration setup. The traceable mount is used to measure the available power from the feedthrough mount. For example, say that 1mW is the dc substituted power level selected on the 1805B. At each frequency the available power from the through mount is measured by the terminating mount/1806 combination as described above. Thus:

$$P_{RF} = \frac{P_{dc1806}}{K_1}$$

where P_{RF} is the available RF power, P_{dc1806} is the dc substituted power as registered in the 1806 bridge by the DVM, and K_1 is the calibration factor of the terminating mount as given to it by the Standards Laboratory.

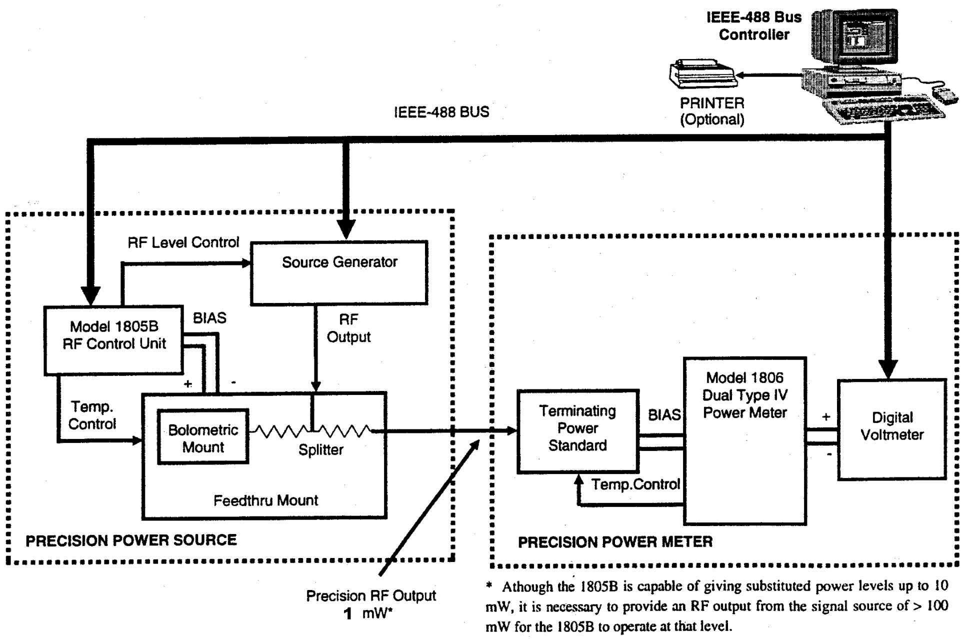


Figure 3-13 System IIA Calibration Setup

However, the available power is also given by:

$$P_{RF} = \frac{P_{dc1805}}{K_2}$$

where P_{dc1805} is the selected substituted dc power in the 1805 bridge, and K_2 is the calibration factor of the feedthrough mount being calibrated. Thus:

$$K_2 = \frac{P_{dc1805}}{P_{RF}} = \frac{P_{dc1805}}{P_{dc1806}} \times K_1$$

This is then the means of providing calibration factors, K_2, to the feedthrough mounts.

Figure 3-14 shows a similar setup for the waveguide mounts. Here,

$$K_2 = \frac{P_{dcbridgeA}}{P_{dcbridgeB}} \times K_1$$

where, $P_{dcbridgeA}$ is the dc substituted power registered by the 1806 for the feedthrough mount under calibration,

$P_{dcbridgeB}$ is the dc substituted power registered by the 1806 for the standard terminating mount, and

K_1 is the calibration factor of the standard terminating mount.

It is important to note that TEGAM has the capability to calibrate all types of mounts against in-house standards that are directly traceable to NIST.

POWER SENSOR CALIBRATION (K_1)

The following procedures are provided as a guideline when performing calibrations. Figure 3-15 shows the setup for using either a digital and analog power meters. These procedures can also be performed over the IEEE-488 Bus using TEGAM software program (SCAL) 189-31 and a PC controller.

100 mW SENSORS

The following procedures provide step by step instructions for manually calibrating 100 mW sensors.

a. Connect the power sensor to the power meter (Refer to Figure 3-17).
b. Place the 1805B RF ON/OFF switch to the OFF position.
c. Zero the power meter and the 1805B.
d. Set 1805 for the desired level. Place the 1805B RF ON/OFF switch to the ON position. The BRIDGE BALANCE meter on the 1805B should momentarily deflect, then go to zero. This indicates a locked and balanced condition.

NOTE

If lock does not occur, either the RF power is insufficient or excessive for lock of RF level control loop. RF output level or frequency may need adjustment.

e. Adjust the generator to the reference frequency, i.e., the frequency at which a particular calibration factor value is desired.
f. Read the power measured (Pm on the display of the power meter, or on the DVM, if using the recorder output).
g. Place the 1805B RF ON/OFF switch to the OFF position.
h. Calculate:

$$K_{1S} = \frac{P_m}{P_{dc1805}} \times K_2$$

where:

K_{1S}	=	cal factor of sensor
K_2	=	known cal factor of feedthrough mount
P_{me}	=	P measured on power meter or DVM
P_{dc1805}	=	1805B power level

i. Compare the calculated K_{1S} at the reference frequency with the desired K_{1S} using the formula below. Then adjust the power meter to the calculated value.

$$P_m = P_{dc1805} \times \frac{desired\ K_{1S}}{calculated\ K_{1S}}$$

i. Repeat steps f through h for all frequencies required for calibration.

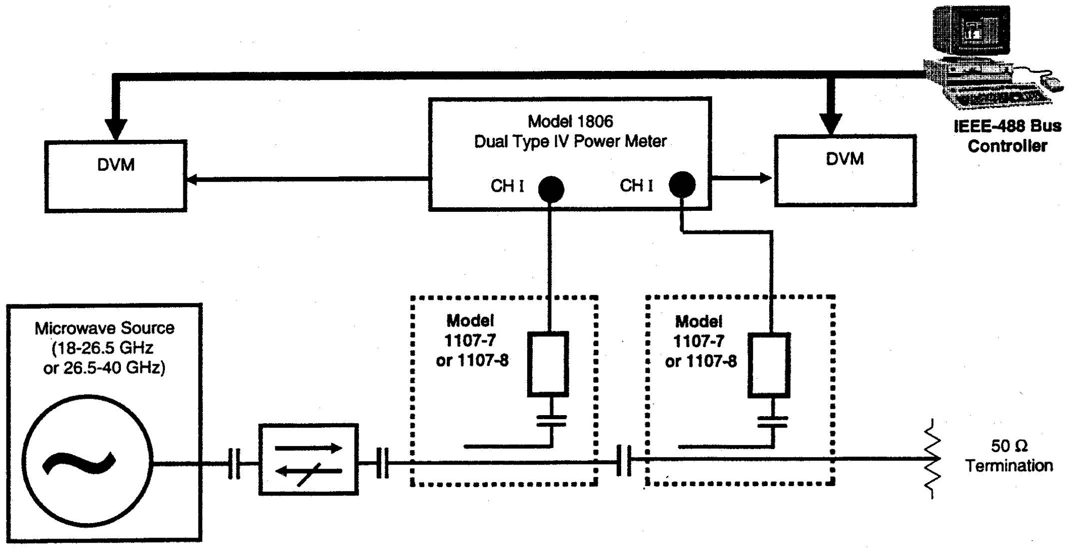


Figure 3-14   18-40 GHz Calibration Setup

HIGH SENSITIVITY SENSORS/UNUSUAL CONNECTOR SENSORS

The following procedures provide step by step instructions for manually calibrating high sensitivity sensors/unusual connector sensors.

a. Connect the power sensor to the power meter (Refer to Figure 3-17).
b. Connect a 30 dB calibrated level dropping attenuator to the output of the feedthrough mount. Connect the power sensor to the attenuator.
c. Place the 1805B RF ON/OFF switch to the OFF position.
d. Zero the power meter and the 1805B.
e. Set 1805B for the desired level. Place the 1805B RF ON/OFF switch to the ON position. The BRIDGE BALANCE meter on the 1805B should momentarily deflect, then go to zero. This indicates a locked and balanced condition.

NOTE

If lock does not occur, either the RF power is insufficient or excessive for lock of RF level control loop. RF output level or frequency may need adjustment.

f. Adjust the generator to the reference frequency, i.e., the frequency at which a particular calibration factor value is desired.
g. Read the power measured (P_m) on the display of the power meter, or on the DVM, if using the recorder output.
h. Place the 1805B RF ON/OFF switch to the OFF position.
i. Calculate:

$$K_{1S} = \frac{P_m}{P_{dc1805}} \times \frac{K_2}{K_A}$$

where:

K_{1S} = cal factor of sensor
K_2 = known cal factor of feedthrough mount
K_A = Loss factor of attenuator at this frequency
P_m = P measured on power meter or DVM
P_{dc1805} = 1805B power level

and

$$K_A = 10^{\frac{A}{10}}$$

where: A = attenuation of the attenuator

j. Compare the K_{1S} at the reference frequency with the required K_{1S} using the formula below. Then adjust the power meter to the calculated value.

$$P_{m_{new}} = P_{m_{old}} \times \frac{K_{1S}\ \text{required}}{K_{1S}\ \text{measured}}$$

k. Repeat steps g through i for all frequencies required for calibration.

NOTE

The same procedure can be used for sensors having peculiar connectors, i.e., not Type N male or 3.5 mm male. An adapter will be required in the setup. Its loss factor is used in exactly the same fashion as that for the attenuator.

CALIBRATION OF TEMPERATURE COMPENSATED THERMISTOR MOUNTS

These sensors, such as the HP478A, are dual thermistor based, just as the TEGAM power standards. They are, however, not ovenized. They have a second set of beads that are not affected by the incident RF power, but are in close thermal contact with the RF power sensing beads. Their job is to sense ambient changes and allow corrections to be applied, and also to provide an offset or "bucking" voltage. This allows the voltmeter being used to make the measurements to be switched to a more sensitive scale, giving greater resolution and ultimately higher accuracy.

In power meters such as the HP432A, the second set of beads allows the user to set up an RF power-off reference, equivalent to the zero in a thermocouple based power meter. The user can then make measurements and basically ignore any changes in ambient that would have affected the reference situation of the RF beads.

The HP432A manual has the following quote: "Normally, in a stable environment, the V_{COMP} output voltage remains constant, not being affected by external RF power; only the V_{RF} output varies during power measurement." What this signifies is that if the ambient environment is closely controlled, measurements and calibrations can be effected without use of the second set of beads. With a suitable adapter cable the thermistor mount can be hooked up to the TEGAM Model 1806 Type IV Power Meter, and calibrated just as if it were an M1110. Figure 3-16 shows this setup. If there is concern over the ambient changing then the second set of beads can be connected to the other channel of the TEGAM Model 1806 and monitored during the process.

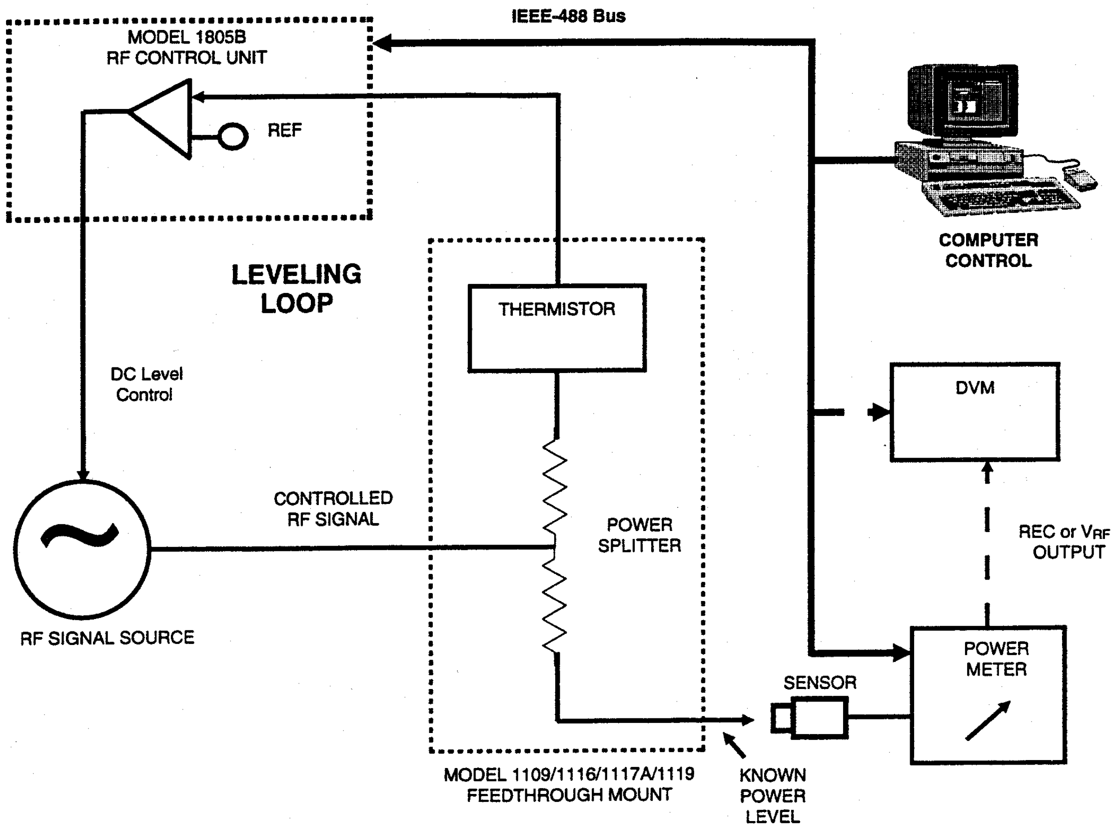


Figure 3-15 Power Meter Calibration Setup

Alternatively, the thermistor mount can be hooked up to an HP432A or other suitable thermistor based power meter. This particular instrument is not IEEE-488 based, and must have a digital voltmeter attached to its output. Figure 3-16 shows this setup. If V_{RF} is used, the setup is run as if the DUT was an M1110, attached to a TEGAM Model 1806.

In either case, the following basic procedure applies:

a. With the RF power off, zero the 1805B, and take a reference reading from the DVM, V_0.
b. Turn the RF power on, and for each frequency in turn, record the new DVM reading, V_1.
c. At each frequency the RF power from the Feedthrough Mount is given by:

$$P_{RF} = \frac{\textit{Selected Substitution Power} \text{ on 1805B}}{K_2\text{, } \textit{the Calibration Factor of the Mount}}$$

and that measured by the DUT is given by:

$$P_{RF} = \frac{(V_0^2 - V_1^2) / 200}{K_{1S}}$$

where K_{1S} is the calibration factor of the DUT.

If there is concern over the ambient temperature changing then a voltmeter should be connected to the V_{COMP} output of the HP 432A. This allows the user to monitor changes in the internal ambient temperature of the mount.

CALIBRATION OF SENSORS WITH NONSTANDARD CONNECTOR TYPES

Not all sensors to be calibrated have N male, 3.5mm male, or GPC-7 connectors. Some have SMA or female connectors. In this case, an adapter has to be inserted between the Feedthrough Standard and the DUT. Such adapters will add an error into the calibration because of their imperfections. Errors can reach several percent at 18 GHz!

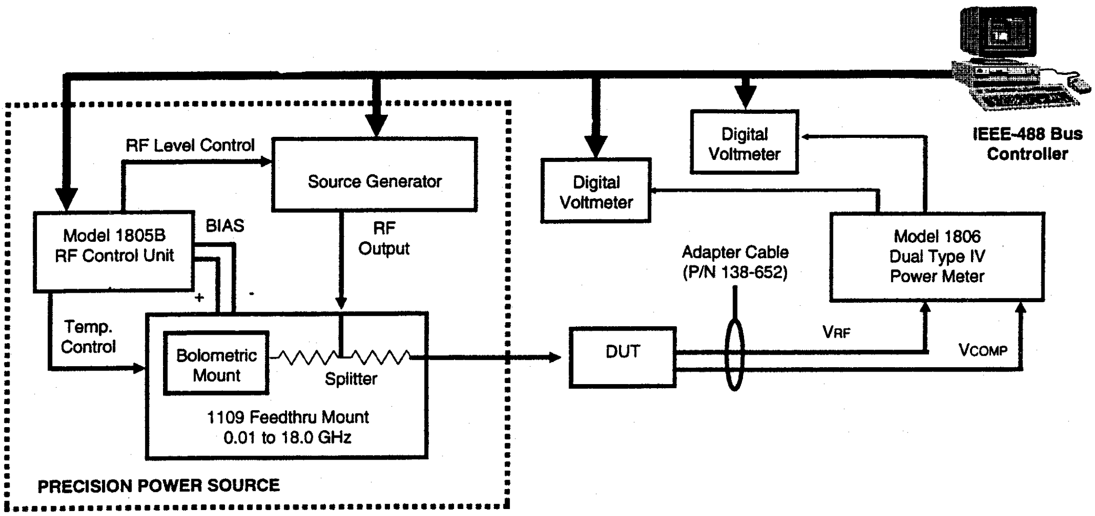


Figure 3-16 Calibration of Compensated Thermistor Mount in Stable Environment

If the performance of the adapter is known, its effect can be removed mathematically. For example, the power incident to a DUT to a first approximation is given by:

$$P_{RF} = \frac{P_{DC}}{K_2} \times K_A$$

where P_{DC} is the value of substituted dc bias selected on the front of the 1805B, K_2 is the feedthrough mount calibration factor, and K_A is the loss factor of the adapter.

Adapter insertion loss can be measured in dB. The conversion is given by:

$$K_A = \frac{1}{10^{\left(\frac{X}{10}\right)}}$$

where X is the insertion loss of the adapter.

The loss factor, K_A, of the adapter can be measured using System II by taking a pair of closely matched adapters, connecting them back to back, and inserting them between a feedthrough mount and a standard. K_A is then given by:

$$K_A = \sqrt{\frac{K_{1S}}{K_1}}$$

where K_1 is the actual calibration factor of the standard, and K_{1S} is the calibration factor as measured with the adapter pair in position between feedthrough and terminating standards.

CALIBRATION USING TWO GENERATORS

Certain sensors straddle a band of frequencies not readily found to be covered by one generator. For example, the HP8482A covers the range from 100 KHz to 4.2 GHz. Very few generators are available that cover that range. Two generators are thus normally required.

Calibration occurs in exactly the same way as before, except that at some crossover frequency, the generator has to be swapped over. This entails switching both the AM control from the rear of the 1805B and the signal cable leading to the power standard.

In certain cases it is possible to put a BNC Tee on the rear of the 1805B, and have both generators permanently connected. In this case, only the RF cable has to be transferred.

Alternatively, the two generators may require the opposite sense level control, in which case the AM port on the rear of the 1805B is connected to one generator, and the NOT AM port to the other.

When running the system under software control, the user is prompted when to make the change. The resulting calibration is then a single file as if calibration entailed the use of only one generator.

CALIBRATING 75 Ω POWER SENSORS

Using the TEGAM 50-75 Ω Minimum Loss Matching Pad (P/N 138-650) as part of the TEGAM System IIA Precision Power Source allows the user to calibrate 75 Ω power sensors over the 0.1 MHz-2.7 GHz frequency range.

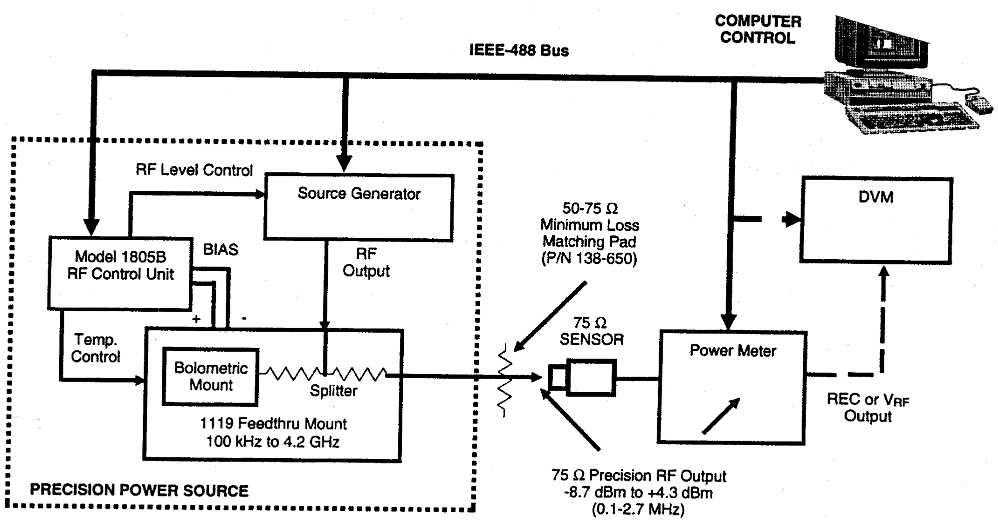


Figure 3-17 75 Ohm Sensor Calibration Setup

Figure 3-17 shows a typical setup for the System IIA Precision Power Source using the calibrated 50-75 Ω Minimum Loss Matching Pad to calibrate 75 Ω sensors such as:

HP8483	100 kHz – 2 GHz
Boonton 51012	100 kHz – 2.5 GHz
Rohde & Schwarz NRV-Z3	1 MHz – 2.5 GHz
WaveTek 85319	30 kHz – 3 GHz (only calibrated over the 100 kHz – 2.7 GHz range)

SENSOR COVERAGE

Table 3-1 is a comprehensive, but by no means exhaustive list of commercially available power sensors that can be readily calibrated using System IIA. The list is broken down into the various manufacturers, and then into sensors by model number. Opposite each sensor is a brief specification for the sensor, plus the possible combination of TEGAM power standards, both coaxial and waveguide, that can be used to provide calibration. As the TEGAM product range is continually expanding, information should be sought from the factory on the most up-to-date method to provide directly traceable calibration for the broader band sensors. The factory can also be contacted with reference to any sensor not listed.

CALCULATING MODEL 1806 ACCURACIES

The specification for the Model 1806 Dual Type IV Power Meter is given as:

Substituted DC Power Accuracy: ± 0.03% ± 2 μW

The actual Model 1806 Power Meter is accurate to better than ± 0.03 up to 25mW. This means that the voltages measured across the 200 Ohm resistor in the self-balancing bridge give the bias power in the thermistor mount to better than ± 0.03 % (Refer to Figure 3-14). Accuracy is lost when the specifications of the voltmeter used to measure this voltage are taken into account.

For example, consider the Fluke Model 8506A digital voltmeter. It has a 6-1/2 digit display with quoted specifications after 90 days of ± 0.001% ± 8 counts in the 10 Volt range.

Consider the bias of the thermistor beads with no RF power present.

$$0.030 = \frac{V_{OFF}^2}{200}$$

where V_{OFF} is the voltage across the 200 Ohm resistor.

$$V_{OFF} = 2.44949 \text{ V}$$

If the incident RF causes the bias to drop by 1 mW, i.e., the dc Substitution power is 1 mW then

$$V_1 = 2.40832 \text{ V}$$

The ± 0.001% figure in the voltmeter accuracy, and the ± 0.003% for the 1806 are linear, and always in the same direction. The ability to correctly measure the 1 mW is thus directly affected by both. The ± 8 counts part of the accuracy can be of any sign or value within these limits, and is a function of the nonlinearity of the voltmeter.

Thus, in the worst case, the V_{OFF} could be read as 2.44957 V, i.e., 2.44949 + 0.00008 and V_1 as 2.40824 V., i.e., 2.40832 - 0.00008.

The former gives an initial bias power of 30.002 mW and the latter a bias power after RF substitution of 28.998 mW. The measurement answer would thus be 1.004 mW, i.e., a 0.4% error. A similar calculation for a 10 mW substituted power gives 0.04% from this alone. This error is far greater than either the voltmeter reference accuracy or the 1806 bridge accuracy.

NOTE

This error can be reduced by using an offset voltage such that the voltmeter can be used on the 1V scale rather than the 10V scale. This is covered in the manual for the Model 1806, IM -140.

Table 3-1 Sensors Calibrated By System IIA

Sensor Model #	Specification	Recommended TEGAM Power Standard(s)
Anritsu:		

MA4603A	100 kHz-2 GHz	F1119, 50-75 ohm Matching Pad (P/N 138-650)
MA4701A	0.01-18 GHz, +20 dBm	F1109
MA4702A	0.01-18 GHz, -20 dBm	F1109 with 30 dB attenuator
MA4703A	0.05-26.5 GHz, +20 dBm	F1117A
MA4704A	0.05-26.5 GHz, -20 dBm	F1117A with 30 dB attenuator
Boonton:		
51100	.01-18 GHz, +20 dBm	F1109
51101	0100 KHz-4.2 GHz, +20 dBm	F1116, F1109, F1119
51102	0.05-26.5 GHz, +20 dBm	F1117A
51012	100 kHz-2.5 GHz	F1119, 50-75 ohm Matching Pad
51012-S/4	100 kHz-2 GHz	F1119, 50-75 ohm Matching Pad
51013	100 kHz-18 GHz	F1116, F1109 with 30 dB attenuator
51015	100 kHz-18 GHz, 1W	F1116, F1109 at 10 mW
51035	18-26.5 GHz (WR 42)	1107-7
51036	26.5-40 GHz (WR 28)	1107-8
51051	0.01-26.5 GHz	F1116, F1117A with 30 dB attenuator
51071	0.01-26.5 GHz	F1109 with adapter (N/2.92 mm), F1117A
51072	0.03-40 GHz	F1109 with adapter (N/2.92 mm) F1107-7 with adapter (WR 42/2.92 mm) F1107-8 with adapter (WR 28/2.92 mm)
51075	100 KHz-18 GHz, +37 dBm	F1116, F1109 with 30 dB attenuator
51200	0.01-18 GHz, +37 dBm	F1109H, 1727A
51201	100 kHz-4.2 GHz, +37 dBm	F1119H, 1727A
HP SENSORS:		
8481D	0.01-18 GHz, -20 dBm	F1109, 30 dB Attenuator
8481A	0.01-18 GHz, +20 dBm	F1109
8481B	0.01-18 GHz, +44 dBm	F1109H, 1727A
8481H	0.01-18 GHz, + 35 dBm	F1109H, 1727A
8482A	100 KHz-4.2 GHz	F1116, F1109 or F1119
8482B	100 KHz-4.2 GHz, +44 dBm	F1119H, 1727A
8482H	100 KHz-4.2 GHz, +35 dBm	F1119H, 1727A
8483	100 kHz-2 GHz	F1119, 50-75 ohm Matching Pad
8485A	0.05-26.5 GHz, +20 dBm	F1117A
8485D	0.05-26.5 GHz, -20 dBm	F1117A with 30 dB attenuator
8485D Opt. 033	0.05-33 GHz, -20 dBm	As for 8485D plus 1107-8 with WR 28/3.5mm Adapter and attenuator
8485A Opt. 033	0.05-33 GHz, +20 dBm	As for 8485A plus 1107-8 with WR 28/3.5 mm Adapter
R8486A	26.5-40 GHz, WR28	1107-8

HP Thermistors:		
478A	0.01-10 GHz	F1109
8478B	0.01-18 GHz	F1109
8478B Opt. 011	0.01-18 GHz	1109WPC or F1109 with adapter
X486A	8.20-12.4 GHz	F1109 with N male/WR-90 adapter
P486A	12.4-18.0 GHz	F1109 with N male/WR-62 adapter
K486A	18.0-26.5 GHz	1107-7
R486A	26.5-40.0 GHz	1107-8
Marconi Instruments		
6910	0.01-20 GHz, +20 dBm	F1109, 1107-7 with adapter
6911	0.01-20 GHz, +20 dBm	1109WPC or F1109 with adapter, 1107-7 with adapter/s (WR 42/GPC-7)
6913	0.01-26.5 GHz, +20 dBm	F1117A, F1119 with adapter
6919	30 kHz-3 GHz	F1119, 50-75 ohm matching pad (only calibrated over 100 kHz-2.7 GHz range)
6920	0.01-20 GHz, -20 dBm	F1109, 1107-7 with adapter (WR 42/N) and with 30 dB attenuator
6923	0.01-26.5 GHz, -20 dBm	F1117A with 30 dB attenuator F1119 with adapter
6930	0.01-18 GHz, +35 dBm	F1109H, 1727A
General Microwave:		
N420C	0.01-12.4 GHz, +10 dBm	F1109
N421D	0.01-12.4 GHz, +20 dBm	F1109
N422C	0.01-12.4 GHz, 0 dBm	F1109 with 30 dB attenuator
M440A	0.01-18 GHz, +10 dBm	F1109 with adapter (N/SMA)
N440A	0.01-18 GHz, +10 dBm	F1109
M441A	0.01-18 GHz, +20 dBm	F1109 with adapter (N/SMA)
N441A	0.01-18 GHz, +20 dBm	F1109
X420C	8.2-12.4 GHz, W/G	F1109 with adapter (UG-39/U/N)
U420C	12.4-18 GHz, W/G	F1109 with adapter (UG-419/U/N)
K420C	18-26.5 GHz, W/G	1107-7
A420C	26.5-40 GHz, W/G	1107-8
M4240A	0.01-18 GHz, +10 dBm	F1109 with adapter (N/SMA)
N4240A	0.01-18 GHz, +10 dBm	F1109
M4241A	0.01-18 GHz, +20 dBm	F1109 with adapter (N/SMA)
N4241A	0.01-18 GHz, +20 dBm	F1109
X4240C	8.2-12.4 GHz, W/G	F1109 with adapter (UG-39/U/N)
U4240C	12.4-18 GHz, W/G	F1109 with adapter (UG-419/U/N)
K4240C	18-26.5 GHz, W/G	1107-7

A4240C	26.5-40 GHz, W/G	1107-8
Wavetek:		
85319	30 kHz-3 GHz	F1119, 50-75 ohm Matching Pad (only calibrated over 100 kHz-2.7 GHz range)
85310	0.01-20 GHz, +20 dBm	F1109, 1107-7 with adapter (WR 42/N)
85320	0.01-20 GHz, -20 dBm	F1109, 1107-7 with adapter (WR 42/N), with 30 dB attenuator
80301A	0.01-18 GHz, High Sensitivity	F1109 with 30 dB attenuator
80302A	0.01-18 GHz, High Sensitivity	1109WPC with 30 dB attenuator
80310A	0.01-18 GHz, High Sensitivity	F1109 with adapter (N/2.92 mm) and 20 dB attenuator
80320A	0.01-18 GHz, High Sensitivity	F1109 with adapter (N/2.92 mm) and 20 dB Attenuator
80330A	0.01-18 GHz, +20 dBm	F1109 with adapter (N/2.92 mm)
80321A	0.01-18 GHz, 0 dBm	F1109
80322A	0.01-18 GHz, +10 dBm	F1109
80325A	0.01-18 GHz, +10 dBm	F1109
85313	0.01-26.5 GHz, +20 dBm	F1109 with adapter (N/3.5 mm), 1107-7 with Adapter (WR42/3.5 mm)
80303B, 80313A, 80323A	0.01-26.5 GHz, -20 dBm	F1109 with adapter (N/2.92 mm) and 20 dB attenuator, 1107-7 with adapter (WR 42/3.5 mm) and attenuator
80324A, 80334A	0.01-40 GHz, +20 dBm	F1109 with adapter (N/2.92 mm) and 20 dB attenuator, 1107-7 with adapter (WR 42/2.92 mm) 1107-8 with adapter (WR28/2.92mm)
80333A	0.01-26.5 GHz, +20 dBm	F1109 with adapter (N/2.92 mm) 1107-7 with adapter (WR 42/2.92 mm)
80304A, 80314A	0.01-40 GHz, -20 dBm	F1109 with adapter (N/2.92 mm) and 20 dB attenuator 1107-7 with adapter (WR 42/2.92mm) and 20 dB attenuator 1107-8 with adapter (WR 28/2.92 mm) and 20 dB attenuator
Rohde & Schwarz:		
NRV-Z1	0.01-18 GHz, +20 dBm	F1109
NRV-Z2	0.01-18 GHz, +27 dBm	F1109H, 1727A
NRV-Z3	1 MHz-2.5 GHz	F1119, 50-75 ohm Matching Pad
NRV-Z4	100 kHz-6 GHz	F1119 and F1109

SYSTEM IIA UNCERTAINTY AND ERRORS

The following paragraphs provide analysis and discussions on the different types of uncertainty and errors that must be considered when using the System IIA.

MEASUREMENT UNCERTAINTY ANALYSIS

Like any other measurement, a transfer of calibration from a power standard to a sensor has uncertainties attached to the results. These include the uncertainty in the factor given to the traceable terminating standard by the Standards Laboratory being used, the instrumentation errors in transferring calibration to the feedthrough mount used for calibration and subsequently to the sensor under test, and the mismatch uncertainties involved in the two transfers.

Figure 3-18 shows a typical traceability sequence, and the associated uncertainties, defined as follows:

Un - Uncertainty in primary calibration by Standards Laboratory,

Ietv - Instrumentation error in transferring calibration to the feedthrough mount,

Me - Uncertainty due to the mismatch between the standard and the feedthrough mount,

Ies - Instrumentation error in transferring calibration from the feedthrough mount to the sensor under test, and

Mes - Uncertainty due to the mismatch between the feedthrough mount and sensor-under-test.

Total uncertainty is then calculated as follows:

$$U_{total} = \sqrt{U_N^2 + I_e^2 + M_e^2 + I_{es}^2 + M_{es}^2}$$

UNCERTAINTY IN PRIMARY CALIBRATION

These figures are calculated by the Standards Laboratory for every frequency at which the terminating standard is calibrated, and normally printed with the calibration factors in the subsequent report.

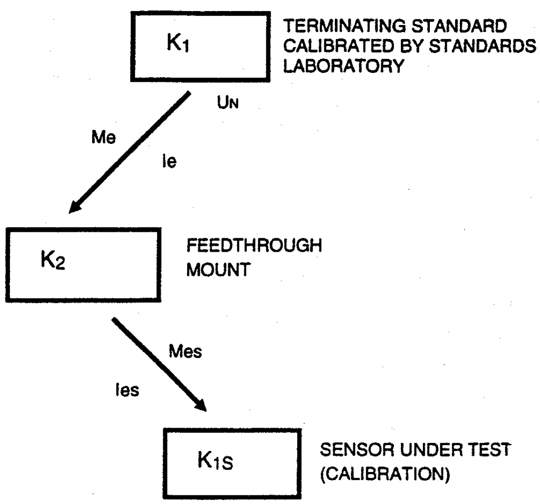


Figure 3-18 A Typical Traceability Sequence

Table 3-2 Instrumentation Error (Ie) Analysis for Transfer from Terminating to Through Mount at 10 mW

Item	Accuracy	Effect %
DC Substitution (1805B)	±0.1% ±5 µW	±0.15
DC Substitution (1806)	±0.003%	±0.003
Digital Voltmeter Accuracy	±0.001%	±0.001
Digital Voltmeter Nonlinearity	±4 µW	±0.04
Connector Repeatability	±0.1%	±0.1
Temperature Drift of Mounts	±0.05%	±0.05
Thermistor Imbalance of Standard (10/1 mW)	±0.1%	±0.0

Instability of Calibration Factor with Time	±0.1%	±0.1
	Worst Case Total	±0.444%
	RSS Value	±0.216%

Table 3-3 Instrumentation Error (Ie) Analysis for Transfer from Terminating to Through Mount at 1 and 2 mW

Item	Accuracy	Effect %	
		1 mW	2 mW
DC Substitution (1805B)	±0.1% ±5 μW	±0.6	±0.35
DC Substitution (1806)	±0.003%	±0.003	±0.003
Digital Voltmeter Accuracy	±0.001%	±0.001	±0.001
Digital Voltmeter Nonlinearity	±4 μW	±0.4	±0.2
Connector Repeatability	±0.1%	±0.1	±0.1
Temperature Drift of Mounts	±0.05%	±0.05	±0.05
Thermistor Imbalance of Standard (10/1 mW)	±0.1%	±0.1	±0.09
Instability of Calibration Factor with Time	±0.1%	±0.1	±0.1
	Worst Case Total	±1.354%	±0.89%
	RSS Value	±0.743%	±0.44%

Table 3-4 Instrumentation Error (Ie) Analysis for Transfer from Terminating Mount to a Sensor Under Test at 1 and 2 mW

Item	Accuracy	Effect %	
		1 mW	2 mW
DC Substitution (1805B)	±0.1% ±5 μW	±0.6	±0.35
Connector Repeatability	±0.1%	±0.1	±0.1
Temperature Drift of Mounts	±0.05%	±0.05	±0.05
Thermistor Imbalance of Standard (10/1 mW)	±0.1%	±0.1	±0.09
Instability of Calibration Factor with Time	±0.1%	±0.1	±0.1
	Worst Case Total	±0.95%	±0.69%
	RSS Value	±0.63%	±0.39%

INSTRUMENTATION ERRORS

These uncertainties are limited by the quoted accuracies of the various equipment involved. Tables 3-2 and 3-3 show examples of calculations for Ie as shown in Figure 3-18.

It should be noted that the primary terminating mount is usually calibrated at 10 mW. If the transfer to the Feedthrough Mount is also performed at 10 mW, then the quoted nonlinearity of the thermistor mount has zero effect. The offset in the 1805B performance and the nonlinearity of the digital voltmeter are also minimized. This is summarized in Table 3-2.

However, Table 3-3 gives the result when this transfer occurs at 1 mW. The standard mount nonlinearity, the 1805B offset and digital voltmeter now have considerable effect. This transfer should then take place at a power level as close to 10 mW as possible. For example, even going to 2 mW reduces the worst case figure to ± 0.894% and the RSS figure to ± 0.439%.

The Voltmeter nonlinearity can also be reduced by choosing one with greater accuracy or by offsetting the voltage and using the voltmeter on a more sensitive range. The figures used come from the 90 day performance of a Fluke Model 8506A.

Table 3-4 shows a calculation for instrument error (Ies) for subsequent transfer to a sensor under test. If performed at 1 mW, the RSS value is ± 0.63%. At 2 mW this becomes ± 0.39%.

Thus, if the through mount is calibrated at 10 mW and a transfer is performed to a sensor under test at 1 mW, the total RSS instrumentation error is ± 0.67%. However, if the through mount was calibrated at 1 mW, the total RSS instrumentation error becomes ± 0.969%!

However, it can be argued that if the through mount in this case is both calibrated and provides calibration while attached to the same 1805B and at the same power, say 1 mW, then the calibration of the mount accounts for the 1805B inaccuracy, since it is constant for both transfers. The RSS value for total instrumentation error then becomes ± 0.47%. This is the most likely scenario for most users of System IIA. It should be noted that by far the dominant component of this value is the digital voltmeter nonlinearity! Table 3-5 shows this calculation.

MISMATCH UNCERTAINTY

The maximum power transfer between two devices occurs when the resistive components of their impedances are equal and the reactive components cancel. Device impedance is characterized by comparing it to a perfect impedance, for example, 50 Ohms.

If the device were connected to a perfect 50 Ohm source, for example, maximum power transfer would only occur if the device had a perfect 50 Ohm impedance. As this is virtually never the case, the concept of reflected power is used to explain the difference between the maximum possible power that can be transferred, and the actual value transferred. The amount of power reflected can be characterized in terms of return loss, or as a voltage in terms of SWR, which is a scalar quantity, or as a reflection coefficient, Γ, which is a vector quantity. The reflection coefficient takes into account both the resistive and reactive components of the impedance. It has magnitude and angle.

When a calibration transfer occurs from a standard to another device an error is created, due to the imperfections of the two impedances. For example, two different standards having different reflection coefficients would yield two different sets of calibration factors when used to calibrate a particular feedthrough mount. The mount has not changed in any way, but the power transfer between the two devices is affected by the impedance interactions.

The maximum error introduced can be calculated using the following equation:

$$M = 1 - \frac{1}{(1 \pm |\Gamma_1| \bullet |\Gamma_2|)^2}$$

where M is the error, and $|\Gamma_1|$ d $|\Gamma_2|$ are the two reflection coefficients involved.

$|\Gamma|$ is related to SWR by the following equation:

$$|\Gamma| = \frac{S - 1}{S + 1}$$

where S is the SWR.

If only the specified value of $|\Gamma|$ is known, then the calculation gives a specified worst case value. If the SWR's of the two devices are known at the various frequencies, then the equation yields an "actual worst case" value, which is smaller.

Table 3-5 Overall Instrumentation Error Analysis for Calibration of Through Standard and Sensor Using the Same 1805B at the Same Level

Item	Accuracy	Effect %
DC Substitution (1805B)	±0.1% ±5 μW	±0.15
Digital Voltmeter Accuracy	±0.001%	±0.001
Digital Voltmeter Linearity	±4 μW	±0.04
Connector Repeatability (Terminating to Through)	±0.1%	±0.1
Temperature Drift of Mounts	±0.05%	±0.05
Instability of Calibration Factor with Time	±0.1%	±0.1
Thermistor Imbalance of Standard (10/1 mW)	±0.1%	±0.1
Connector Repeatability (Through to Sensor)	±0.1%	±0.1
Temperature Drift of Mount	±0.05%	±0.05
Instability of Calibration Factor with Time	±0.1%	±0.1
DC Substitution (1805B) Drift with Time	±0.1%	±0.1
	Worst Case Total	±0.444%
	RSS Value	±0.216%

If both magnitude and angle of Γ are known for both devices, then the resulting calibration can be corrected! This is termed Γ-correction.

Frequency Range (GHz)	1109 SWR	Sample Sensor SWR	Specified Worst Case Error %
0.01-.03	1.06	1.40	1.0
0.03-.05	1.06	1.18	0.5
0.05-2.0	1.06	1.10	0.3
2.0-8.0	1.06	1.18	0.5
8.0-12.4	1.10	1.18	0.8
12.4-18	1.10	1.28	1.2

The above listing shows an example calculation of "specified worst case". This is based on the specifications for both the feedthrough mount and a sample sensor.

Frequency (GHz)	1109 SWR	Sample Sensor SWR	Specified Worst Case Error %
0.01	1.01	1.40	0.17
0.1	1.03	1.10	0.15
1.0	1.03	1.10	0.15
2.0	1.03	1.18	0.24
8.0	1.04	1.18	0.33
18.0	1.08	1.28	0.95

The above listing shows an example calculation where the actual measured SWR performance of the feedthrough mount is known, and used together with the specifications for the sensor-under-test to obtain a partial actual worst case error.

Γ-CORRECTION

Figure 3-18 shows a typical 2-step calibration transfer. In the first step, a terminating mount, having been calibrated by a Standards Laboratory such as NIST, is used to calibrate a Feedthrough Mount. The normal equation used to derive the calibration factor K_2 for the Feedthrough Mount is:

$$K_2 = K_X \quad \frac{P_{dc1805}}{P_{dc1806}}$$

where P_{dc1805} is the Feedthrough Mount dc substitution power, shown by the setting on the 1805B, P_{dc1806} is the Calibrated Terminating Mount dc substitution power as shown by the 1806, and K_1 is the calibration factor of the Calibrated Terminating Mount.

If the impedances are taken into account the equation becomes:

$$K_2 = K_1 \ x \ \frac{P_{dc1805}}{P_{dc1806}} \quad x \quad \frac{1}{|1 - \Gamma_1\Gamma_2|^2}$$

where Γ_1 and Γ_2 are the reflection coefficients of the Calibrated Terminating Mount and Feedthrough Mount being calibrated, respectively.

In the second step the basic equation is:

$$K_{1S} = K_2 \ x \ \frac{P_m}{P_{dc1805}}$$

where K_2 is the Feedthrough Mount calibration factor, P_{dc1805} is the dc substituted power in the Feedthrough Mount, as selected on the 1805B, and P_m is the power reading of the combination of sensor being calibrated and its power meter.

Taking the impedances into account yields the following equation:

$$K_{1S} = K_2 \ x \ \frac{P_m}{P_{dc1805}} \quad x \quad |1 - \Gamma_2\Gamma_1|^2$$

where $\Gamma_1$and Γ_2 are the reflection coefficients of the Feedthrough Mount and sensor under test, respectively.

The effect of performing Γ correction is to reduce the mismatch errors involved in the calibration process, i.e., Me and Mes, to zero.

EFFECT OF ADAPTERS AND ATTENUATORS ON UNCERTAINTY

High sensitivity sensors such as the HP8481D and Marconi 6920 cannot be calibrated at 1 mW. They are normally calibrated at -30 dBm, which is within their linear region. This is achieved by using a 30 dB attenuator attached to the output of the feedthrough mount. From the point of view of uncertainty, this adds one more connection causing further mismatch errors, and a device, whose insertion loss has an uncertainty attached to it.

The same is true for sensors having odd connector options, e.g., the General Microwave Model M440A, which has an SMA connector, and where an adapter must be inserted between the feedthrough power standard output and the device-under-test.

The Marconi 6919 is a 75 ohm sensor. In this case, a minimum loss matching pad must be inserted between power standard at 50 ohms, and device-under-test.

Figure 3-19 shows the extra uncertainties due to an intermediate device such as an attenuator or adapter.

The full uncertainty calculation now becomes:

$$U_{total} = \sqrt{U_N^2 + I_e^2 + M_e^2 + I_{es}^2 + M_{es}^1 + M_{es}^2 + M_A^2}$$

where all uncertainty values are RSS.

Mismatch uncertainties M_{es}^1 and M_{es}^2 are calculated for each individual connection in the same fashion as is described earlier

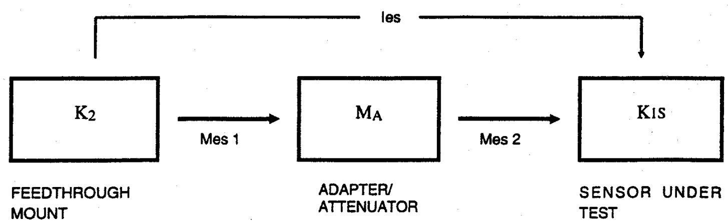


Figure 3-19 Uncertainty Diagram Using an Intermediate Device

The value M_A is the uncertainty in the value of the intermediate device. This device will be measured on some system that will have measurement uncertainties. The specially calibrated Weinschel Model 44-30 used to calibrate high sensitivity sensors is measured at TEGAM with a typical worst case uncertainty in value of ± 0.07 dB. This is equivalent to ± 1.6%.

A further potential error has not been addressed. This is the repeatability of the extra coaxial connection. As this is about 0.1%, it has little effect on the final RSS number and can be reasonably ignored. This assumes precision connectors in good condition!

As an example, consider an HP8481D having actual measured SWR performance as shown in the following table. The total uncertainty figure is then calculated assuming a calibration taking place at 1 mW with the instrumentation uncertainty, Ies, at ± 0.63%. For simplicity, the Model 44-30 is assumed to have equal input and output reflection coefficients. The major component throughout is the ±1.6% of M_A .

The equation used is as follows:

$$U_{total} = \sqrt{U_2^2 + I_{es}^2 + M_{es1}^2 + M_{es2}^2 + M_A^2}$$

where U_2 is the uncertainty of the feedthrough mount being used.

Frequency (GHz)	1109 Actual SWR	Sensor Actual SWR	44-30 Actual SWR (both parts)	Total Uncertainty %
0.01	1.01	1.30	1.08	2.2
0.1	1.03	1.12	1.10	2.1
1.0	1.03	1.10	1.10	2.1
2.0	1.03	1.12	1.10	2.1
8.0	1.04	1.13	1.15	2.2
18.0	1.08	1.30	1.20	3.2

NIST TRACEABILITY

The calibration factor from a NIST calibrated Model 1110 terminating power standard is transferred to the System IIA 1109 feedthrough power standard with a typical loss of only 1/2 of 1% in transfer uncertainty for 132 traceable frequencies.

As shown in Figure 3-22, traceability of the Model 1110 mount supplied as a part of System IIA is derived from the TEGAM Calibration Lab Model 1109. An additional loss of 1/2 of 1% in transfer uncertainty occurs with this method due to the three tiers of calibration. As an alternative, System IIA may be supplied with Model 1110 mounts calibrated directly by NIST, also shown in Figure 3-22. The NIST calibrated Model 1110 can be returned to NIST for recalibration on an annual or biennial basis.

Depending on logistics, a user of multi-System IIA installations may elect to maintain traceability using a single Model 1110 thermistor mount on a rotational basis between sites and the main reference laboratory.

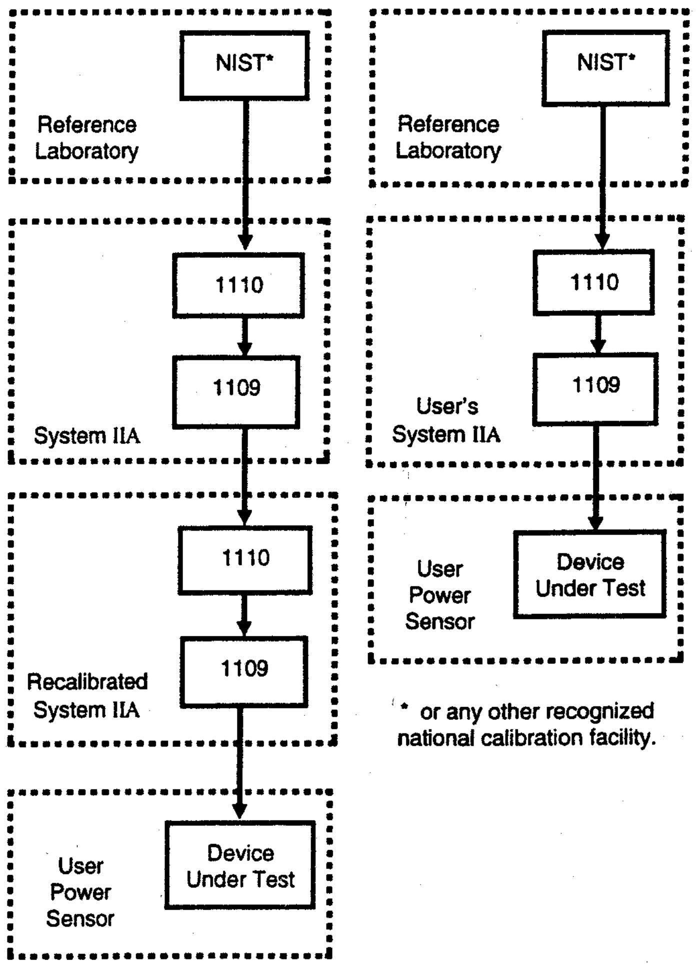
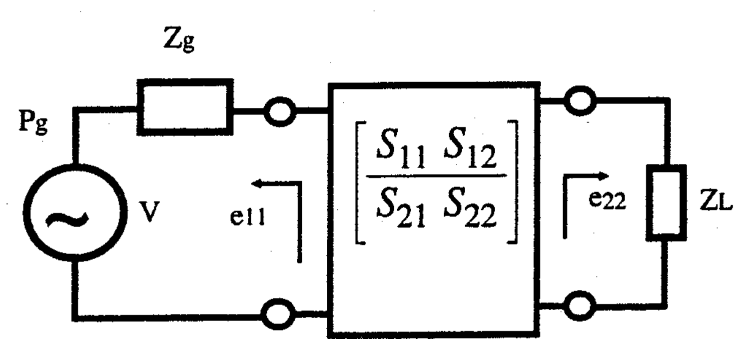


Figure 3-20 Traceability

CORRECTION OF REFLECTION COEFFICIENT ERRORS

The following is a theoretical analysis of the method used to correct mismatch between devices. Consider a generator connected to a load through an arbitrary two port.



The maximum available power from the generator (conjugate match) is given by:

Equation 1: $$P_g = \frac{|V|^2}{4R_g}$$

The equivalent source reflection coefficient is e_{11} and the load reflection coefficient is e_{22}. The power absorbed in the load is then given by [1].

Equation 2: $$P_L = \frac{(1 - |e_{11}|^2)\,|S|^2(1 - |e_{22}|^2)}{|1 - e_{11}S_{11} - e_{22}S_{22} + e_{11}\,e_{22}[S]\,|^2} \quad x \quad P_g$$

where [S] is the determinant of the S-matrix:

Equation 3: $[S] = S_{11}S_{22} - S_{21}S_{12}$

Assume that the load is a Model 1806 power meter and the generator is a Model 1807 transfer standard. The absorbed power P_L is then related to the substituted dc power:

Equation 4: $P_{dc1} = \eta 1 \text{ x } P_L$

Since the calibration factor K_1 is derived from the efficiency $\eta 1$:

Equation 5: $K1 = (1 - |e_{22}|^2)\,\eta 1$

the substituted dc power can be written:

Equation 6: $$P_{udc1} = \frac{K_1}{1 - |e_{22}|^2} \text{ x } P_L$$

A calibration factor K_2 is also defined for the transfer standard as the substituted dc power divided by the emitted power:

Equation 7: $$K_2 = \frac{P_{dc2}}{|1 - |e_{11}|^2| \text{ x } P_g}$$

The corresponding efficiency is then given by:

Equation 8: $\eta 2 = (1 - |e_{11}|^2) K_2$

which is <u>not</u> the same relation as defined for a terminating power standard.

Equations 6 and 7 can then be solved for P_L and P_g, which are then substituted in equation 2:

Equation 9: $$K_1 = \frac{|S_{21}|^2}{|1 - e_{11}S_{11} - e_{22}S_{22} + e_{11}e_{22[S]}|^2} \times \frac{P_{dc}2}{K2}$$

OR

Equation 10: $$K_1 = \frac{|1 - e_{11}S_{11} - e_{22}S_{22} + e_{11}e_{22[S]}|^2}{|S_{21}|^2} \times \frac{P_{dc}1}{P_{dc}2} \times K_2$$

If the power meter is connected directly to the transfer standard, then $S_{11} = S_{22} = 0$ and $S_{12} = S_{21} = 1$, so equation 10 simplifies to:

Equation 11: $$K_1 = |1 - e_{11}e_{22}|^2 \times - \frac{P_{dc}1}{P_{dc}2} \times K_2$$

Equations 10 and 11 are the final relations between the calibration factors and substituted dc powers including the effects of the reflection coefficients.

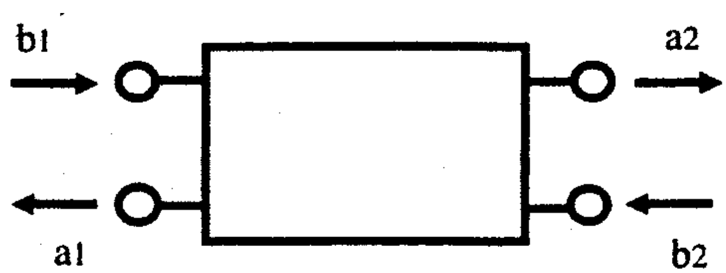
S-PARAMETERS OF MULTIPLE TWO PORTS

There are frequent applications where more than one two-port is inserted between the transfer standard and the device under calibration. One example is an attenuator and an adapter for calibrating low power power meters. The System II software therefore includes a routine which combines the S–parameters of two two-ports into one equivalent two-port where S-parameters are then used in the error correction.

NOTE

For the system software to run correctly, port 1 of one two-port device must be coupled to port 2 of the other two-port device. The port numbers for a two-port device are specified in "S" parameter files.

S-parameters are based on ratios of incident and reflected waves where:



Equation 12: $$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} /b_1 & a_1/b_2 \\ a_2/b_1 & a_2/b_2 \end{bmatrix}$$

OR

Equation 13: $a_1 = S_{11}b_1 + S_{12} \times b_2$

$$a_2 = S_{21}b_1 + S_{22} \times b_2$$

This equation can be rearranged such that a_1 and b_1 are functions of a_2 and b_2. The new parameters are known as T-parameters:

Equation 14: $a_1 = T_{11}b_2 + T_{12}\, a_2$

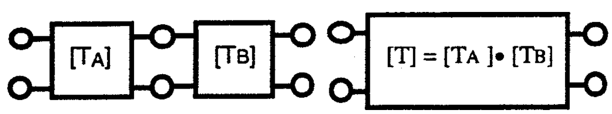
$$b_1 = T_{21}b_2 + T_{22}\, a_2$$

Where Tix is given by:

Equation 15:

$$\begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} = \frac{1}{S_{21}} \begin{bmatrix} S_{12}S_{21} - S_{11}S_{22} & S_{11} \\ -S_{22} & 1 \end{bmatrix}$$

The T-parameters concept has the benefit of being able to calculate the T-parameters of two cascaded two ports simply by multiplying the two T-matrices.



The S-parameters of the combined two ports are then simply found by the inverse procedure:

Equation 16:

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \frac{1}{T_{22}} \begin{bmatrix} T_{12} & T_{11}T_{22} - T_{12}T_{21} \\ 1 & -T_{21} \end{bmatrix}$$

RETURN LOSS/SWR MEASUREMENTS

All of the System IIA power standards are shipped complete with full “S” parameter data. The only unknown is then likely to be the SWR of the sensor under test. Normally, SWR is measured using a scalar system, either swept or stepped. System IIA is a scalar system, although its principal function is power sensor calibration. As such, it can be used together with a suitable return loss bridge to measure the performance of passive devices or sensors.

Figure 3-21 shows a System IIA Precision Power Source setup using an SWR bridge connected between the precision source output and the sensor being “calibrated”. In this case, two different “calibrations” are performed. First, a short or open is connected to the test port of the SWR bridge. This has the effect of reflecting all of the power from the precision source through to the sensor. The device under test is then connected to the test port of the SWR bridge, and a second calibration of the sensor performed. In this case, only a portion of the power is reflected from the device under test through to the sensor. The ratio of the two powers is the return loss of the device under test.

The above is shown mathematically as follows:

Case 1. The total power is reflected from the short/open.

$$K_{1r} = \frac{P_{mr}}{P_{rf}}$$

where, P_{rf} is the power emanating from the precision source,
P_{mr} is the power as registered by the power meter attached to the terminating sensor, and
K_{1r} is the calibration factor of the sensor.

Case 2. The device under test attached to the bridge test port.

$$K_{1t} = \frac{P_{mt}}{P_{rf}}$$

where P_{mt} is the power as now registered by the power meter attached to the terminating sensor
K_{1t} is the equivalent calibration factor of the sensor.

The calibration factors are denoted by K_1 as this is the normal identification of the calibration factor of a terminating sensor.

In this measurement sequence, the so-called calibration factors have little relevance to the performance of the terminating sensor. If the measurements are being performed by hand, all that is needed is the power meter readings. However, the System IIA software gives results in terms of calibration factors. To cover a large number of measurement frequencies, it is thus more expedient to use what the software gives, i.e., calibration factors. It can be seen from the equations that the calibration factor is proportional to the measured power, so that they are interchangeable.

The return loss of the device under test is thus the ratio of the so-called calibration factors, i.e.,

$$\frac{K_{1r}}{K_{1t}} \text{ In power ratio terms, or } 10 \log \frac{K_{1r}}{K_{1t}} \text{ in db terms.}$$

Shown in the actual data taken with the setup shown in Figure 3-21.

The three columns show the calibration factor with a short, with an open and with an unterminated 10 dB attenuator, giving a 20 dB return loss. The first two columns show that unlike under normal calibration conditions, where a calibration factor close to 100%, i.e., 1.000 is expected, the insertion loss of the SWR bridge gives a starting point at around 5%, or 0.05.

Frequency	Short	Open	10 dB ATT	Open/Short Average	Calc. SWR
200 MHz	0.0551	0.0498	0.0010	0.0525	1.32
400 MHz	0.0538	0.0489	0.0009	0.0514	1.30
600 MHz	0.0477	0.0508	0.0008	0.0493	1.29
800 MHz	0.0471	0.0506	0.0007	0.0489	1.27
1000 MHz	0.0448	0.0477	0.0005	0.0463	1.23
1200 MHz	0.0427	0.0478	0.0005	0.0453	1.23

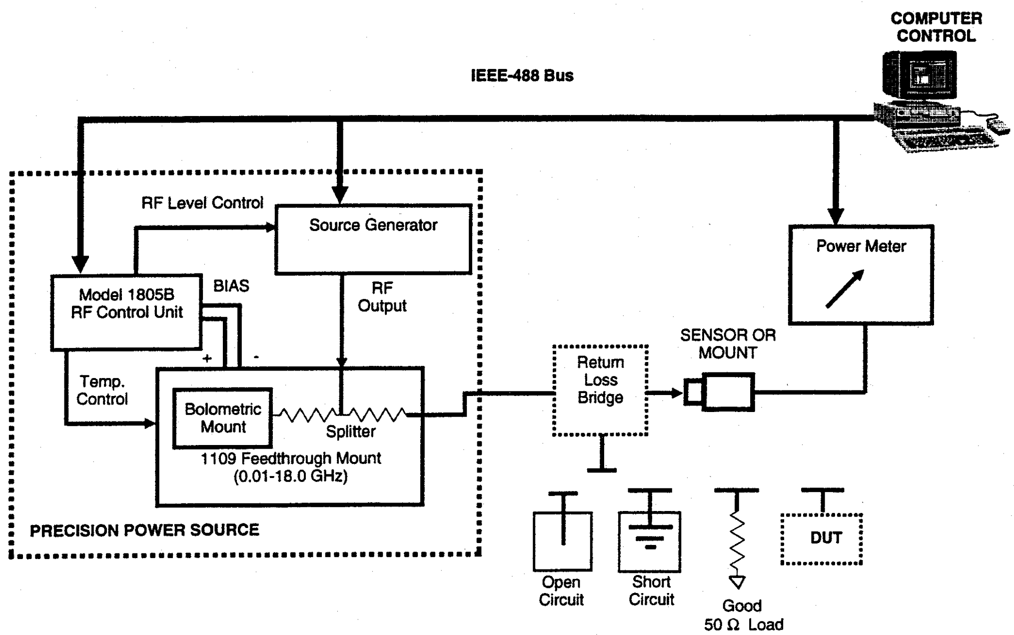


Figure 3-21 SWR Measurement Configuration

Bridges typically have around 6.5 dB of insertion loss on each transition, giving 13 dB total. This directly translates into a calibration factor around 1/20th of maximum, i.e., 0.05.

Starting at 0.05 mes that the practical return loss range is limited to about 20 dB, as shown by the unterminated 10 dB attenuator. In SWR terms this is equivalent to 1.22:1.

There are two factors that govern this range limitation; power range and measurement resolution.

The most typical level at which to perform sensor calibrations with System IIA is 1mW. This means that a calibration factor of 1.0000 at the power meter/sensor being calibrated represents 1 mW. With the bridge in place, as shown in Figure 3-24, the working power at the terminating power sensor now starts at a reference level of 0.05 mW or –13 dBm. A DUT with a return loss of 20 dB is then equivalent to a measurement level of –33 dBm.

If the terminating power meter/sensor is a thermistor power standard such as the M1110 attached to a Model 1806 Dual Type IV Power Meter, which is in turn attached to a standard voltmeter, the power level of –33 dBm, i.e., 0.5 µW, becomes somewhat inaccurate.

Assuming that the inaccuracies of the Power Standard and Model 1806 are systematic, and are constant for all the power levels, the major source of inaccuracy is from the digital voltmeter. The catalog specification for a typical arrangement is ± 0.03% +2 µW. This potential error thus completely overshadows the power levels mentioned above.

One way to improve matters is to raise the “calibration” lower level. For example, if 10 mW were available, a 20 dB return loss would give measurements around –23 dBm, i.e., 5 µW. This is a tenfold increase in working levels. However, the calibration factors still start at approximately 0.05 as before.

Refer to TEGAM Application Note #213 for more information about measuring SWR using the System IIA.

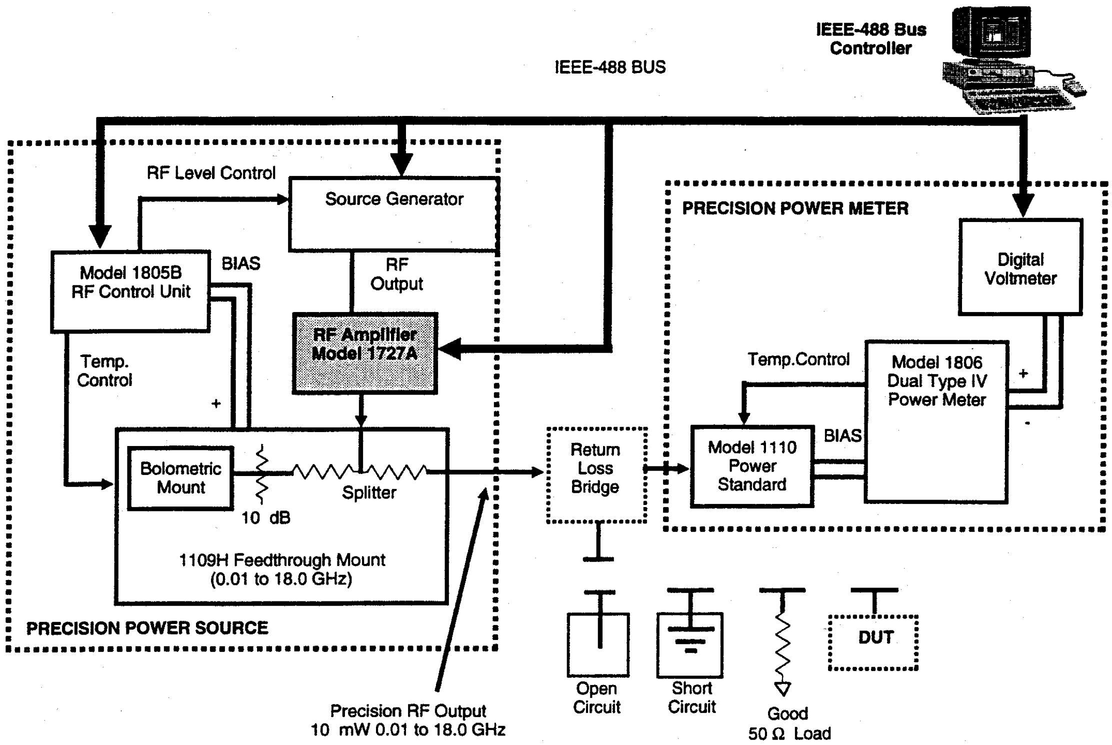


Figure 3-22 100 mW SWR Measurement Configuration

SECTION IV MAINTENANCE

GENERAL

This section provides general maintenance practices for daily operation of the System IIA. Also included are instructions for contacting TEGAM should a problem arise or more information be needed.

MAINTENANCE

The following paragraphs contain procedures outlining operational checkouts, inspection, preventive maintenance, and special cleaning instructions for the System IIA.

OPERATIONAL CHECKOUT

Accomplish the operational checkout of the System IIA by performing all operational checkout procedures located in Section V of this manual (Performance Test and Verification). If a fault or problem occurs during these tests, perform the fault isolation procedures located in Section V of this manual.

INSPECTION

Perform a visual inspection (Table 4-1) in conjunction with the maintenance activities schedule when a malfunction is suspected, or whenever an assembly is removed or replaced.

PREVENTIVE MAINTENANCE

While the System IIA requires very little preventive maintenance, it should not be subjected to physical abuse, severe mechanical shock, high humidity, or operating temperatures outside the specification range. The instruments should be kept free of excessive dirt and dust, since these can interfere with connector functions and with normal heat dissipation. For cleaning instructions refer to “special cleaning instructions” below. The following paragraphs provide the preventive maintenance that is to be performed on the System IIA.

Fan Filters

To ensure that the System IIA instruments that require ventilation are properly ventilated, check each power supply's fan filter on a daily basis for excessive dirt and dust. Wipe clean whenever necessary. About every 60 days or when necessary remove the fan filter media from the instrument and clean per the appropriate instrument O & S manual.

Connectors

Care should be taken to prevent strain on the interconnecting cables, since damage here may not always be apparent. Occasionally check the external cables and connectors for signs of cracked insulation and/or bent or worn pins. Tests show that connectors must be clean for accuracy and stability. This requires an inspection and cleaning of each connector immediately before use. When cleaning precautions are observed regularly, connectors can maintain their stability for over several thousand connection cycles. Refer to Appendix A for more information about cables and connectors.

Verification Test

The Calibration and Verification procedures described in Section V should be performed every six mouths or after any repair or replacement of a System IIA assembly or instrument. If a fault or problem occurs during these tests, perform the fault isolation procedures located in Section V.

SPECIAL CLEANING INSTRUCTIONS

The cleaning procedures for System IIA are divided into five general groups: microwave coaxial cable assemblies, machined surfaces and hardware, chassis cleaning, and connector cleaning. Table 1-3 provides a list of consumables recommended to perform these procedures.

Microwave Coaxial Cable Assemblies

Appendix A (located at the end of this manual) provides all the necessary procedures for care, cleaning, and handling of microwave coaxial cable assemblies.

Machined Surfaces and Hardware

To remove light dirt and dust from mechanical parts such as castings, covers and other hardware proceed as follows:

WARNING

Compressed air used for cleaning and/or drying can create airborne particles that may enter the eye. Goggles/faceshields should be worn. DO NOT direct air stream towards self or other personnel. Pressure should be restricted to a maximum 15 psi to avoid personal injury.

CAUTION

- Under no circumstances use a wire brush, steel wool, or abrasive compound. Using these items will cause extensive damage to the instrument's surface.
- DO NOT use a nylon bristle brush in solvent as the bristles may dissolve and cause damage to the circuit card or component.

a. Use 5 psi of clean, moisture-free compressed air or preferably dry nitrogen to blow loose dirt and dust from surface of item.
b. Briskly brush isopropyl alcohol onto area to be cleaned with a fiber-bristle brush.
c. Remove residue with lint-free cloth and repeat step "b" as a rinse.
d. When parts are thoroughly clean, dry parts using 5 psi of clean, moisture-free compressed air or preferably dry nitrogen.
e. Clean smaller mechanical parts or hardware by dipping into a container of isopropyl alcohol . Remove dirt by brushing with fiber-bristle brush after parts have been immersed for several hours.
f. Remove parts from isopropyl alcohol and rinse by immersing into a different container of isopropyl alcohol.
g. When parts are thoroughly cleaned, dry parts using 5 psi of clean, moisture-free compressed air or preferably dry nitrogen.

Table 4-1 System Inspection

Item	Inspection
Top, Bottom, Side Panels	Dents, cracks, scratches, or other damage; loose or missing handles, brackets, or mounting hardware; damaged mounts; corrosion or excessive dirt.
Connectors	Bent, broken or corroded pins; cracked or broken inserts; cracked or broken shell; loose or missing mounting nuts, washers, or screws.
Hardware	Stripped threads, missing washers, corrosion, or other signs of damage.
External Wiring	Frayed, broken, or abraded insulation; improperly dressed or tied cables; broken, corroded, or poorly soldered conductors at the terminals; missing or damaged sleeving at connector terminals.
Painted Surfaces	Scratches, chips, or peeling.
Preformed Packing	Nicks, burrs, or foreign materials present.
Switches	Signs of overheating; loose or broken terminals; lack of positive action.

Chassis Cleaning

Clean chassis using a lint-free cloth moistened with water and mild detergent. For harder to clean areas, such as inside corners of chassis, use a vacuum cleaner.

Connector Cleaning

Where small amounts of rust, corrosion, and/or oxide deposits are present on connectors, clean externally with a soft-bristle brush , aluminum wool, or internally with an acid brush; then wash with a noncorrosive solvent. MIL-C-83102 is recommended. Exercise care to ensure no metal filing or residue remains inside the connector and the connector is thoroughly dry. Where rust, corrosion, and/or oxide deposits are present in large quantities, replace the connector.

CONTACTING TEGAM

DO NOT return any instrument or component to the factory without prior authorization. When an instrument or component has to be returned to the factory, Section I provides the necessary information to contact and return the instrument or component to TEGAM.

REPAIR

Repair of any assembly located in the System IIA instruments should be performed in accordance with the applicable O & S manual.

SECTION V
PERFORMANCE TESTING,CALIBRATION & TROUBLESHOOTING

GENERAL

This section contains the calibration and troubleshooting procedures to ensure that the System IIA Automatic Power Meter Calibration System is operational and performing within its design specifications. The calibration procedures located in this section should be performed after any repair or replacement of an assembly, module, or component located within the System IIA instruments and as regular maintenance procedures. Troubleshooting is also provided to isolate a problem to a faulty instrument or system component.

OPERATIONAL CHECKOUT

The following paragraphs provide procedures to perform a full System IIA Operational Checkout. The individual instruments that make up a System IIA can be independently tested according to procedures in their respective manuals.

COAXIAL SYSTEM TO 18 GHz

Performing the following procedure will verify that the system is able to transfer a calibration from a standard to the feedthrough mount and back with adequate stability and accuracy. Listed below is the recommended equipment to perform the test.

TEGAM Model System IIA Power Sensor Calibration System consisting of:

MODEL	NOMENCLATURE
Gigatronics GT9000/ Wiltron 68047B	Synthesized Signal Generator 0.01-18 GHz + 10 dBm
TEGAM 1805B	RF Power Level Control Unit 0.5 to 10 mW dc substitution
TEGAM F1109	Feedthrough Coaxial Power Standard, 0.01 to 18 GHz
TEGAM 1806	Dual Type IV Power Meter
TEGAM M1110	Terminating Coaxial Power Standard, 0.01 to 18 GHz
HP 3458A	Digital Voltmeter, 8-1/2 digits
189-31	SCAL System IIA Software
Any	486 PC Based Controller with GPIB interface card and Windows 3.1
Any	Windows Compatible Printer

a. Connect the equipment as in Figure 5-1.
b. Allow several hours for system warm-up before making measurements.
c. Using the terminating mount as a standard, perform a calibration of the feedthrough mount selecting 10 runs, and covering all 132 NIST calibration frequencies. Use 1 mW.
d. Check that upon completion the standard deviation in the printout is in the fourth decimal place of the calibration factor. Check that the calibration factors are all greater than 0.80.
e. If the system shows variability check all connections and/or allow more time to stabilize.
f. Now, using the feedthrough mount as the standard, calibrate the terminating mount. Run 10 calibrations.
g. Check that the standard deviation in the printout is in the fourth decimal place of the calibration.
h. Check that the calibration factors so produced are the same as the original calibration factors of the terminating mount to within ±0.002.

COAXIAL SYSTEM TO 100 MHz/4.2 GHz

The test described above can be performed in exactly the same fashion for the Models 1111/1116 operating to 100 MHz, and for Models 1119 and 1120 that operate to 4.2 GHz. A Signal Generator operating from 0.1 MHz to 4.2 GHz + 10 dBm will be required to perform this procedure.

COAXIAL SYSTEM TO 26.5 GHz

The test described above can be performed in exactly the same fashion for the Models 1117/1117A/1118 operating to 26.5 GHz. A Signal Generator operating from 0.05 to 26.5 GHz + 10 dBm will be required to perform this procedure.

WAVEGUIDE SYSTEMS

Performing the following procedure will verify that the system is able to transfer a calibration from a standard to the feedthrough mount and back again with adequate stability and accuracy. Listed below is the recommended equipment to perform the test from 18 to 26.5 GHz.

MODEL	NOMENCLATURE
Wiltron 68X59	Source Generator (18-26.5 GHz) + 5 dBm
Any	Isolator - WR-42, 20 db
TEGAM 1806	Dual Type IV Power Meter
HP 3458A	Digital Voltmeter, 8-1/2 digits (2)
TEGAM 1107-7	RF Power Transfer Standard, WR-42, Waveguide (2)
189-31	SCAL System IIA Software
Any	PC Based Controller with GPIB interface card and Windows 3.1
Any	Windows Compatible Printer

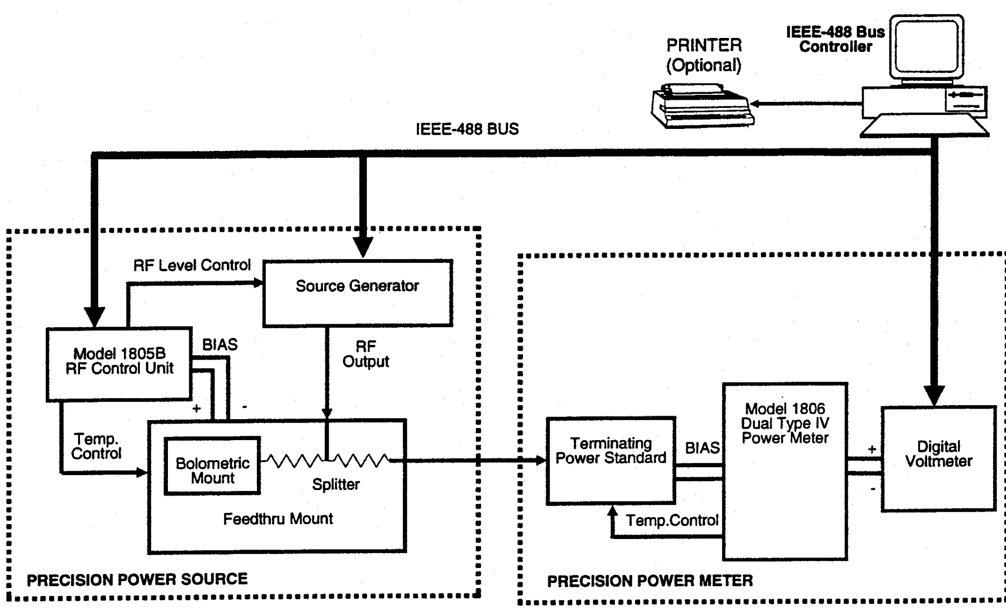


Figure 5-1 Coaxial Calibration Setup

a. Connect the equipment as shown in Figure 5-2.
b. Allow several hours for system to warm-up before making measurements.
c. Using the terminating mount as a standard, perform a calibration of the feedthrough mount selecting 10 runs.
d. Check that upon completion the standard deviation in the printout is in the fourth decimal place of the calibration factor. Check that the calibration factors are all greater than 0.60
e. If the system shows variability, check all connections and/or allow more time to stabilize.
f. Using the feedthrough mount as the standard, calibrate the terminating mount. Run 10 calibrations.
g. Check that the standard deviation in the printout is in the fourth decimal place of the calibration.
h. Check that the calibration factors so produced are the same as the original calibration factors of the terminating mount to within the uncertainty.

NOTE

Repeat the above measurements (steps (a through h) for the 26.5 - 40 GHz range if used, using the 1107-8 mounts. The source should be changed to a unit covering that range. Suitable generators include the Wiltron 6740B, 6763B and 6769B. Source level should be set as high as possible. The isolator should be WK-28, 20dB.

CALIBRATION

When supplied TEGAM feedthrough and terminating standards have valid calibrations that are directly traceable to NIST. Subsequent calibrations of the terminating mounts can be effected by NIST in Boulder, Colorado, or by some other calibration and standards laboratories throughout the World. Feedthrough mounts can either be calibrated by the user, or can be returned to TEGAM.

CALIBRATION INTERVAL

Within the first few years it is recommended that all standards are calibrated at least once per year. Once a standard has proved to be stable long-term, the calibration interval may be extended. The following is a quote from NIST Calibration Services Users Guide, 1989, NIST Special Publication 250:

"Thermistor-type bolometer units have shown adequate stability over long periods of time (approximately 10 years) and warrant long recalibration intervals. Two- or three-year recalibration intervals are recommended once the stability of a bolometer unit has been verified."

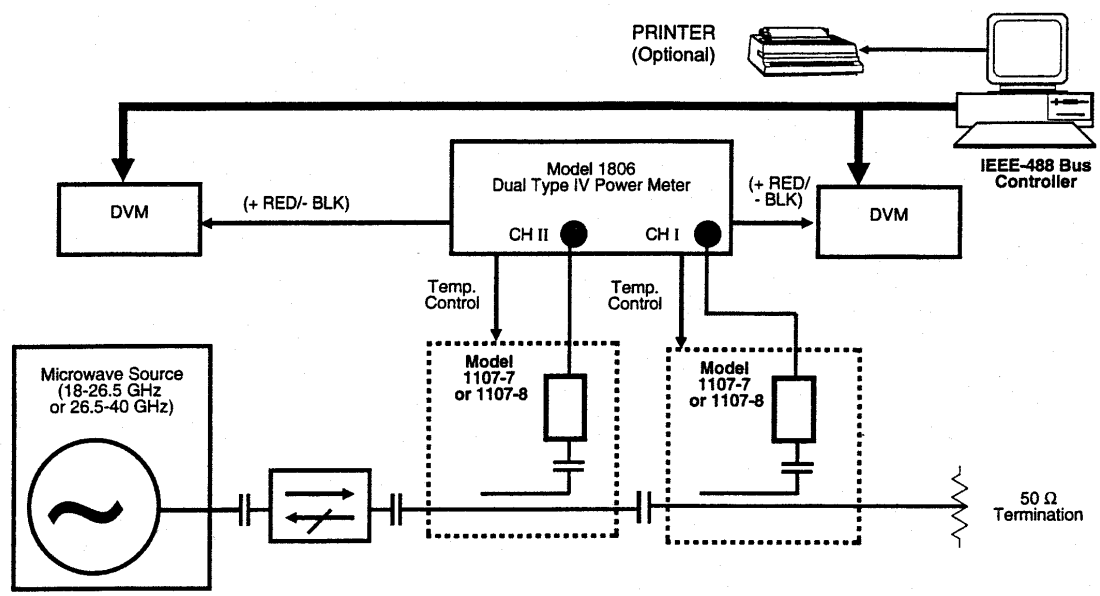


Figure 5-2 Waveguide Calibration Setup

Feedthrough mounts that are used regularly for a heavy workload should be compared to the standard on a regular basis, as wear of the connector interface could affect performance.

TEGAM provides calibration services for all System IIA components as follows:

COMPONENT	CYCLE
Model 1806 Type IV Power Meter	1 year
Model 1805B RF Control Unit	1 year
Model 1807A RF Transfer Standard	1 year
Model 1107-7 Waveguide Mount	1 year

Model 1107-8 Waveguide Mount	1 year
Model 1109 Feedthrough Mount	1 year
Model 1110 Terminating Mount	1 year
Model 1111 Terminating Mount	1 year
Model 1116 Feedthrough Mount	1 year
Model 1117A Feedthrough Mount	1 year
Model 1118 Terminating Mount	1 year
Model 1119 Feedthrough Mount	1 year
Model 1120 Terminating Mount	1 year
Model 1727A RF Amplifier	1 year

CALIBRATION DATA RECORD

Keeping a record of all the instrument and mount calibration data can provide a reference for periodic calibration, troubleshooting of the System IIA, after repair testing, and to obtain maximum factory assistance.

CALIBRATION OF F1109/F1116/F1117/F1119

The following procedures and information are provided as a guide line when calibrating any TEGAM Model F1109, F1116, F1117 or F1119 Feedthrough Power Standard. Listed below is the necessary equipment to perform the calibration. Setup the equipment as shown in Figure 5-1.

MODEL	NOMENCLATURE
Gigatronics GT9000/Wiltron 68000 Series or equivalent	Synthesized Signal Generator 0.01-18 GHz + 10 dBm or suitable generator to cover frequency range of mount being calibrated
TEGAM 1805B	RF Power Level Control Unit 0.5 to 10 mW dc substitution
TEGAM 1806	Dual Type IV Power Meter
TEGAM M1110	Terminating Coaxial Power Standard, 0.01 to 18 GHz, Calibrated (1109 only)
TEGAM M1111	Terminating Coaxial Power Standard, 0.1 to 100 MHz, Calibrated (1116 only)
TEGAM M1118	Terminating Coaxial Power Standard, 0.05 to 26.5 GHz, Calibrated (1117 only)
TEGAM M1119	Terminating Coaxial Power Standard, 0.1 MHz to 4.2 GHz, Calibrated (1119 & 1116 only)
HP3458A	Digital Voltmeter, 8-1/2 digits
189-31	SCAL System IIA Software
Any	486 PC Based Controller with GPIB interface card and Windows 3.1
Any	Windows Compatible Printer

The basic process in calibrating a standard coaxial feedthrough mount is to step a precision source containing the mount through its calibration frequencies one at a time, and at each frequency to use a precision power meter to measure the output. Its calibration factor is then calculated as follows:

$$K_2 = \frac{P_{dc1805} \text{ x } K_1}{P_{dc1806}}$$

where K_2 is the calibration factor of the feedthrough mount being calibrated,
K_1 is the calibration factor of the terminating standard,
P_{dc1805} is the dc substitution power selected on the 1805B,
and P_{dc1806} is the dc substitution power as indicated on the 1806/Voltmeter combination.

It should be noted that NIST normally calibrates at 10 mW. The most accurate transfer is thus also achieved at 10 mW selected on the 1805B. However, if subsequent sensor calibrations are performed at 1 mW, it may be expedient to transfer to the feedthrough mount at 1 mW. Section III should be consulted for information on calculating uncertainties.

Mismatch uncertainty can be reduced if the actual SWR of both standard and feedthrough mount are known. Mismatch error can be basically removed if the magnitude and angle of the reflection coefficients of both terminating and feedthrough mounts are known.

The calibration equation then becomes:

$$K_2 = K_1 \times \frac{P_{dc1805}}{P_{dc1806}} \times \frac{1}{|1 - \Gamma_1\Gamma_2|^2}$$

where:
P_{dc1805} is the Feedthrough Mount dc substitution power, shown by the setting on the 1805B,
P_{dc1806} is the Calibrated Terminating Mount dc substitution power as shown by the 1806, and
K_1 is the calibration factor of the Calibrated Terminating Mount.
K_2 is the calibration factor of the feedthrough mount being calibrated,
Γ_1 and Γ_2 are the reflection coefficients of the Calibrated Terminating Mount and Feedthrough Mount being calibrated, respectively.

The reflection data for the terminating mount can be measured using a vector network analyzer. The reflection data for the feedthrough mount can be measured by removing the splitter. After reattachment of the splitter the feedthrough mount must be recalibrated.

When performing the procedure the following points should be observed:

a. Check that the 1805B bridge is balanced with the RF off, i.e., the meter reads zero. It can be adjusted to zero with the fine and coarse controls.
b. Check that the voltmeter reading for RF off is stable to the last digit.
c. Check that when the RF is turned on that the 1805B needle goes back to zero. If not, it indicates that the generator does not have enough power.
d. It is preferable that the system software is used to perform the whole process. Refer to IM-235 for details.

It should be noted that the F1116 is usually calibrated using a M1111, the F1109 is usually calibrated using a M1110 and the F1119 is usually calibrated using a M1120. Also make note that two generators may be required to cover the frequency range of the Model F1119 (refer to Section III for using two generators).

CALIBRATION OF 1107-7/1107-8

The following procedures and information is provided as a guideline when calibrating any TEGAM Model 1107-7 or 1107-8 Power Standard. Listed below is the necessary equipment to perform the calibration. Setup the equipment as shown in Figure 5-4.

MODEL	NOMENCLATURE
Wiltron 68X59 Series	Source Generator (18 - 26.5 GHz) + 5 dBm
Any	Source Generator (26.5 - 40.0 GHz)
Any	Isolator-WR-42, 20 db
Any	Isolator-WR-28, 20 db
TEGAM 1806	Dual Type IV Power Meter
HP 3458A x 2	Digital Voltmeter, 8-1/2 digits
TEGAM 1107-7	RF Terminating Power Transfer Standard with Calibration (18-26.5 GHz)
TEGAM 1107-8	RF Terminating Power Transfer Standard with Calibration (26.5-40 GHz)

The basic process is to step the source through each of the calibration frequencies. At each frequency, the dc substituted power in both channels of the 1806 is compared to allow transfer of calibration from the terminating 1107-7 on the right to the feedthrough version on the left.

The terminating mount is calibrated to measure the power incident upon its input waveguide port. Thus, the feedthrough mount is calibrated according to the power that emanates from its output port.

The calibration factor for the feedthrough mount at each frequency is given by

$$K_2 = K_1 \times \frac{P_{dc2}}{P_{dc1}}$$

where K_2 is the calibration factor of the feedthrough mount,
K_1 is the NIST traceable calibration factor of the terminating mount,
P_{dc1} is the dc substituted power in channel 1 of the 1806, the channel attached to the terminating mount,
and P_{dc2} is the dc substituted power in channel 2 of the 1806, the channel attached to the feedthrough mount under test.

TROUBLESHOOTING

Table 5-1 is provided as an aid in solving problem or locating defective instruments and/or components during the use of System IIA. Read and perform all steps. When a defective instrument or component is located replace or repair using its applicable manual. After the instrument is repaired or replaced perform all associated test and calibration procedures located in this section.

Table 5-1 System IIA Troubleshooting

Trouble	Probable Cause	Remedy
1. With the RF ON the 1805B Bridge Balance Meter Needle is to the left of zero.	Not enough power from generator for mW selection on the 1805B	Check the mW setting on the 1805B. If the 1805B is correct, perform the following: a. Inspect all cables to ensure that they are in good condition and that they are connected correctly from instrument to instrument. If the cables are damaged repair/replace. b. If the cables are OK, then check the generator in accordance with its manual. If necessary repair defective generator. Note: If used in the calibration setup, check the output of the TEGAM 1727A Amplifier. If defective, test, troubleshoot and repair using IM-267. c. If generator OK, test and troubleshoot the 1805B and feedthrough mount in accordance with the appropriate manual. If feedthrough mount is found defective, replace or send to TEGAM for repair. If necessary, repair defective 1805B per IM-200.
2. With the RF ON the 1805B, Bridge Balance Meter needle is to the right of zero.	Too much power from generator for mW selection on the 1805B.	Check the mW setting on the 1805B. If the 1805B is correct, perform the following: a. Is the TEGAM 1727A or other amplifier in use when it should be? If

		so, remove from setup. b. If not, then check that the cable from the 1805B AM/AM connector to the generator is in good condition and is properly connected. If the cable is damaged, repair/replace. c. If the cable is OK, then check that the generator is in the correct mode for external leveling. d. If the generator is in the correct mode, check the generator external leveling control and IEEE-488 bus control. e. If generator is OK, test and troubleshoot the 1805B and feedthrough mount in accordance with the appropriate manual. If feedthrough mount is found defective, replace or send to TEGAM for repair. If necessary, repair defective 1805B per IM-200.
3. With the RF ON the 1805B Bridge Balance Meter oscillates.	Leveling loop unstable	Check that the correct AM output on the 1805B is being used to control the generator. Depending on the generator, the user may need to change to the opposite polarity. If this is good, then perform the following: a. Inspect all cables to ensure that they are connected correctly from instrument to instrument (especially to the mount). If the cables are damaged, repair/replace. b. If the cables are OK, then check the generator in accordance with its manual. If necessary, repair/replace defective generator. NOTE: If used in the calibration setup, check the output of the TEGAM 1727A Amplifier. If defective, test, troubleshoot, and repair using IM-267. c. If generator is OK, test and troubleshoot the 1805B and feedthrough mount in accordance with the appropriate manual. If feedthrough mount is found defective, replace or send to TEGAM for repair. If necessary, repair defective 1805B per IM-200.
4. On either the 1805B or 1806, the heater current meter needle is oscillating.	The temperature control circuitry is unstable	Troubleshoot the 1805B or 1806 in accordance with the appropriate manual (IM-140 for 1806 and IM-200 for 1805B).
5. On the 1806, the bias voltage is outside 2.44949 ± 0.0287 V with no RF input (TEGAM coaxial mounts only).	Mount not at the correct temperature.	Check that the 1806 indicates a steady heater current close or within the green band. If correct, then perform the following: a. Has the mount had at least 1 hour to stabilize. If not, allow the mount more time (1-2 hours) to stabilize. b. If after 1-2 hours the bias voltage is still

		not within the accepted range, inspect all cables from the 1806 to the voltmeter. If the cables are damaged, repair/replace. c. If the cables are OK, then ensure that the correct resistance has been selected on the 1806. d. If the resistance switch on the 1806 is set to the correct position, connect the mount to the other channel of the 1806 and verify the 1806 indicates a steady heater current close to or within the green range. e. If after allowing time to stabilize the bias voltage is within limits, repair the 1806 per IM-140. If the mount still has trouble substitute a known good mount. If substitution corrects the problem, replace or send to TEGAM for repair. f. If problem still exists after mount substitution, repair the 1806 per IM-140 and verify the voltmeter accuracy.
6. Calibration Factors are all zero.	System Fault	If the 1806 is used in the setup check that the voltmeter is correctly connected to the 1806 and the cables are not damaged. If the cables are damaged, repair/replace. Otherwise, perform the following: a. Check that the sensor is connected to the feedthrough mount. b. If sensor is correctly connected in the software, check that for a high sensitivity sensor a 30 dB attenuator file is being called up to modify the results. c. If so, then check the file for corruption of data. d. If OK, check that the test power meter is functioning properly per its maintenance manual.
7. When used with the 1806, the voltmeter indicates high up to 11 V.	Defective 1806. Or Mount not connected properly.	Ensure that both bias leads are properly connected to the mount and 1806 and are not damaged. If the cables are damaged, repair/replace. Otherwise, perform the following: a. Attach the mount and voltmeter to the other channel of the 1806. If the voltmeter now has the correct readings repair the 1806 per IM-140 b. If still incorrect, substitute a known good mount. If substitution corrects the problem, replace or send to TEGAM for repair. c. If problem still exists after mount substitution, repair the 1806 per IM-140.
8. Software errors.	System/controller problems.	Refer to System IIA Software Manual IM-235 to ensure all equipment and software is set up correctly

9. Calibration Factors look suspect, i.e., shape of frequency curve has changed from the frequency curve in the previous calibration or the number looks incorrect.	Leveling Loop problem or data files incorrect.	Repeat the calibration run several times to verify the problem. If the numbers vary, inspect all cables to ensure that they are in good condition and that they are connected correctly from instrument to instrument and verify that all instruments and mounts are stable. If the cables are damaged, repair/replace. If an instrument or mount is not stable, troubleshoot problem using Items 1 through 4 of this table. Otherwise, perform the following: a. Try the calibration runs at a different power level/setting. If the calibration runs now look correct, then check the generator in accordance with its manual. If necessary, repair defective generator. NOTE: If used in the calibration setup, check the output of the TEGAM 1727A Amplifier. If defective, test, troubleshoot and repair using IM-267. b. If generator is OK, test and troubleshoot the 1805B in accordance with IM-200. If necessary, repair defective 1805B per IM-200. c. If the calibration data is still incorrect but repeatable, then check the following: 1. Sensor damage – the connector and SWR plot may provide the picture. 2. Data files for the mounts and adapters have not been corrupted. 3. That the correct resistance is selected on the 1806 if used.
10. Standard deviation of multiple runs is too large, i.e., in third or higher decimal place.	System is not stable, is not warm or connectors are damaged/dirty.	Ensure the System is stable by allowing a further warm-up. If the 1806 is being used, check that the voltmeter reading is stable to the fourth digit at least over a period of one minute or so. If not troubleshoot using item 5 of this table. If OK, or not using the 1806, inspect all cables to ensure that they are in good condition and that they are connected correctly from instrument to instrument and verify that all instruments and mounts are stable. Do not over torque RF connectors. If the cables are damaged, repair/replace. If an instrument or mount is not stable, troubleshoot problem using items 1 through 3 of this table. If everything seems correct, check the feedthrough mount splitter for damage. Ensure that the female contacts are not spread apart. If defective, return to TEGAM for repair.

APPENDIX A
CARE AND HANDLING OF MICROWAVE COAXIAL CABLE ASSEMBLIES

CARE AND HANDLING OF ASSEMBLIES

To ensure accurate measurements and optimal performance of TEGAM products, the microwave coaxial cable assemblies used in system and test setups must be properly used and maintained. Proper connections, routine inspection of all cables, and cleaning of the connectors are extremely important procedures that can prolong the longevity and accuracy of equipment.

CABLE INSPECTION

Routinely check external cables for signs of cracked insulation, dents, twists, flattening, signs of jacket abrasion, or other signs of abuse. Wrinkles in the jacket indicate that the minimum bend radius has been exceeded. Most often, this occurs near the marker tubes and connectors.

Also inspect the connector interfaces for the following:

- Bent pins (male)
- Bent or missing tines (female)
- Worn or chipped plating
- Damaged or displaced dielectric inserts
- Thread damage
- Folded or mushroomed outer interface rims
- Mushroomed pin shoulders (male) or tine ends (female)
- Score lines on pins and outer interface rims visible to the unaided eye
- Recessed or protruding pins

It is advisable to clean the connectors prior to inspection to make subtle damage more apparent. If any of the above is noted, replace the assembly before its further use results in equipment damage. Also inspect the mating connectors for similar damage.

Table A-1 provides both TEGAM specifications and MIL-C39O12C data for the pin height of the various types of connectors. Pin height is defined as the vectorial distance along a horizontal axis of the pin shoulder from the electrical/mechanical reference plane.

Table A-1 Pin Height Specifications

CONNECTOR TYPE	MALE	FEMALE	SEXLESS	MIL-C-39012C
7mm	NA	NA	0.000 + .000 - .002[2]	See Fig. A-1
N type	0.208 min	0.207 max	NA	See Fig. A-2
SMA	0.000 + .000 - .010	0.000 + .000 - .030	NA	See Fig. A-3
WPM	0.000 + .000 - .010	0.000 + .000 - .010	NA	See Fig. A-3
WPM-3	0.000 + .000 - .005	0.000 + .000 - .005	NA	See Fig. A-3
WPM-4	0.000 + .000 - .005	0.000 + .000 - .005	NA	See Fig. A-3
BNC	+ .210 + .230	+ .186 + .206	NA	See Fig. A-4
TNC	+ .210 + .230	+ .186 + .206	NA	See Fig. A-5

Inspect the connector interface for signs of debris. Debris may be in the form of:

- Plating chips or other metal particles
- Dust or dirt
- Oily films
- Other miscellaneous foreign particles

If signs of debris are present, clean the connector interface as directed below in Cleaning Connector Interfaces.

MAKING INITIAL CONNECTIONS

Exercise caution when mating cables. Poor connections lead to poor system performance. They can also damage not only the cable assembly, but more significantly, front or rear panel connectors on the equipment itself, which may be more difficult to repair.

Aligning Connectors

Align the center lines of two connectors before actual mating. Male retaining nuts contain a small amount of necessary play that may make it possible to mate the threads without the pins being properly aligned. Pin misalignment can damage pins and dielectric inserts.

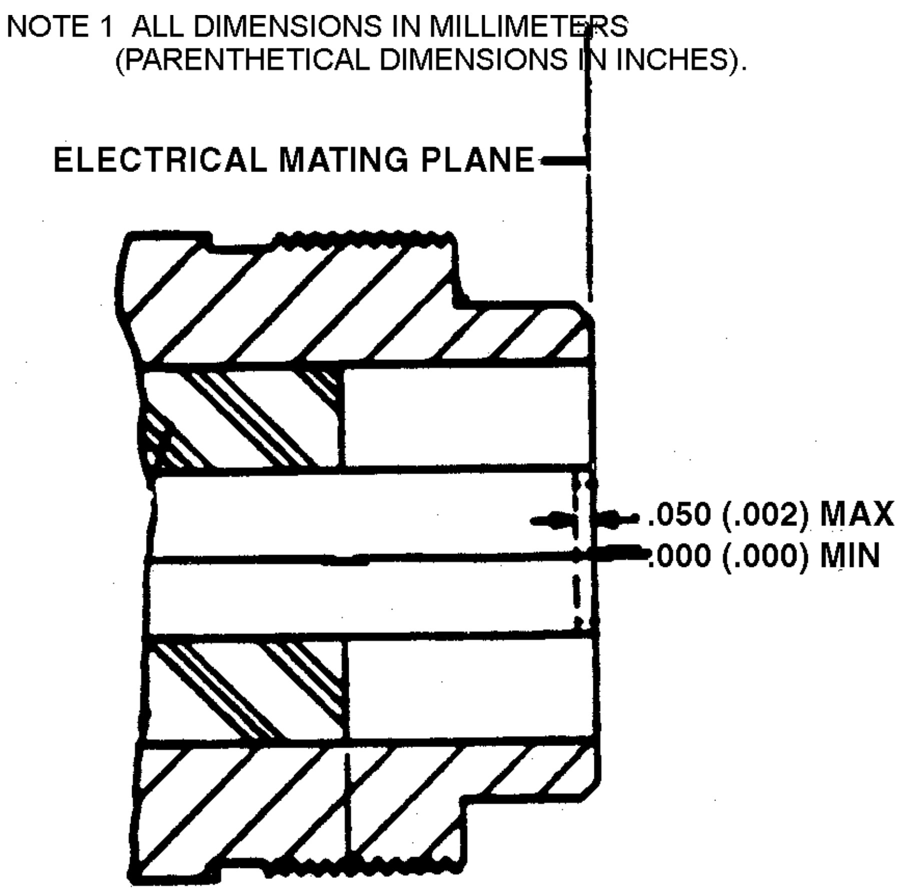
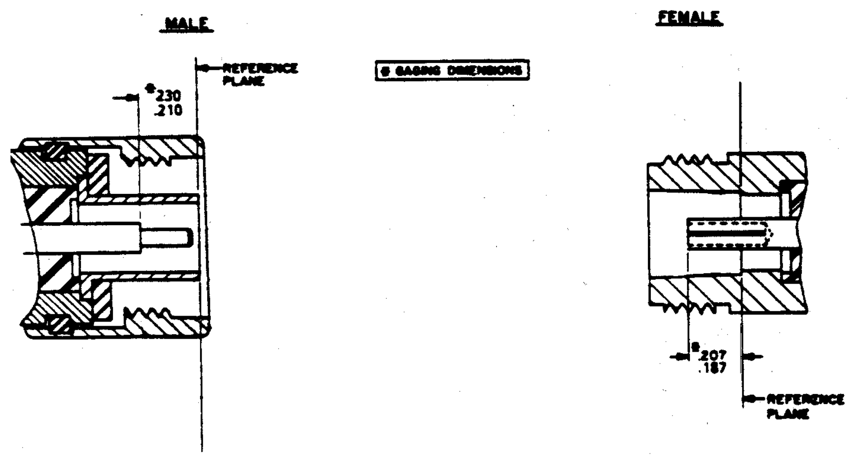


Figure A-1 Important Interface Dimensions for Type 7 MM, Precision Connectors (IEEE Std 287)



INCHES	CM
.003	.008
.016	.406
.060	.152
.062	.157
.065	.165
.121	.307
.163	.414
.187	.475
.207	.526
.210	.533
.318	.808
.330	.838
.340	.864
.359	.912
.405	1.030
.626	1.593
.630	1.600

Figure A-2 Important Interface Dimensions for Type 7 MM, Precision Connectors (IEEE Std 287)

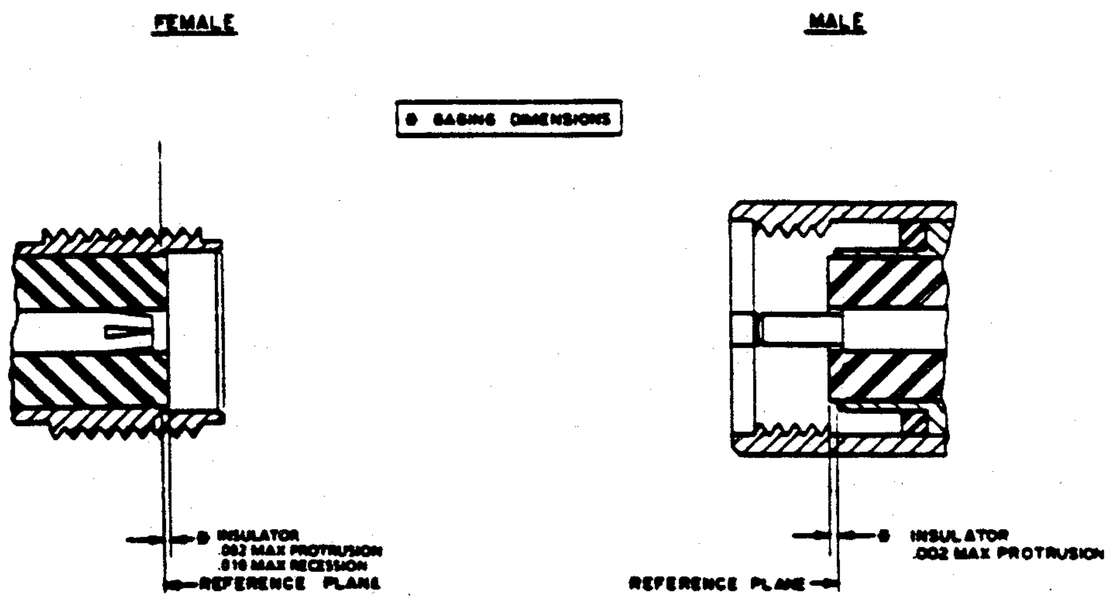


Figure A-3 Important Interface Dimensions for Type SMA, Class II Connectors (MIL-C-39012/55&57)

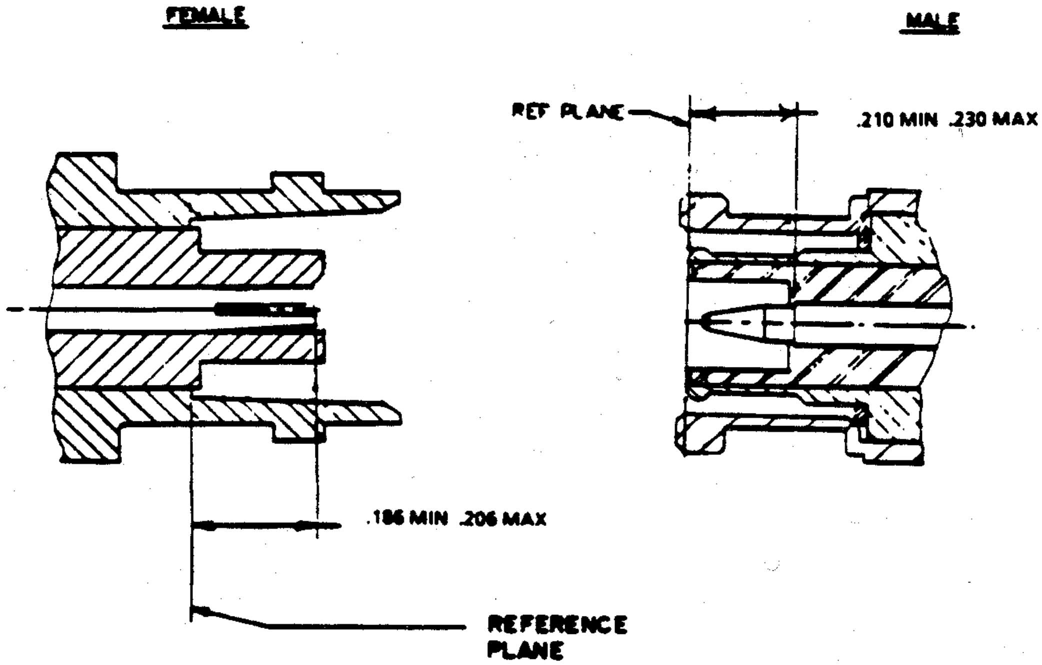


Figure A-4 Important Interface Dimensions for Type BNC, Class II Connectors (MIL-C-39012/16&17)

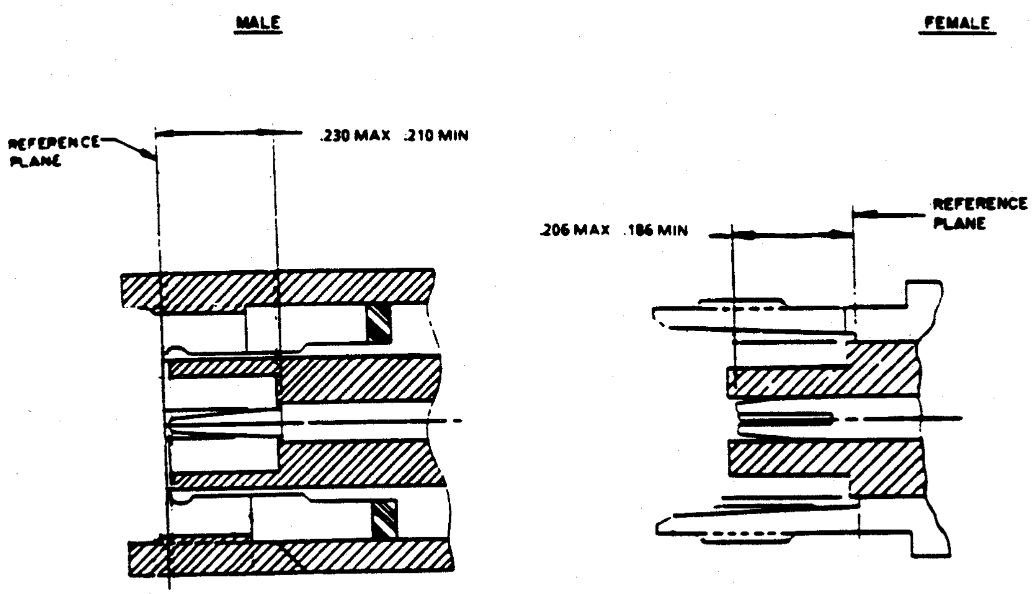


Figure A-5 Important Interface Dimensions for Type TNC, Class II Connectors (MIL-C-39012/26&27)

MATING CONNECTORS

Gently mate the connectors by hand, taking care not to force the coupling nut at the slightest resistance. It is often possible to feel whether or not the pins are mated. If the coupling nut is difficult to turn, either the pins are not mated, the coupling nut is cross-threaded, or one of the connectors has been damaged by excess torque.

Never hold a male connector coupling nut stationary while screwing a female connector into it. This rotation can erode the plating and damage both the outer interface rim as well as the pin. If the pins become locked, serious damage can result to both the equipment and the cable assembly.

ENSURING PROPER CONNECTOR TORQUE

OVERTORQUING

Once connectors have been properly mated, apply only the proper amount of torque. Overtorquing damages both connectors involved. Also, a connector that has been damaged by overtorquing, in turn, damages every connector to which it is subsequently mates. It usually leads to poor system performance as well. Overtorque can cause:

- Bent pins
- Recessed or protruding pins
- Recessed or protruding dielectrics
- Chipped plating
- Damaged coupling threads
- Coupling nut retaining ring damage
- Mushroomed outer interface shells
- Mushroomed pin shoulders

HEX-NUT TYPES

To mate a connector of the hex-nut type, al ways use a torque wrench set to the correct torque value. Tighten the connector slowly until the wrench snaps. Tightening too quickly can cause the wrench to exceed its set limit. Do not snap the wrench more than once as this also causes overtorque.

KNURLED NUTS

Tighten connectors with knurled nuts by hand. If this does not provide sufficient tightness use a hex-nut connector and torque wrench instead. Never use pliers to tighten a connector. Table A-2 recommends torque specifications for the various types of connectors.

Table A-2 Connector Torque Recommendations

CONNECTOR TYPE	RECOMMENDED TORQUE
7 mm connector with hex nuts	14.0 in/lbs. ±1 in/lbs.
Type N connector with hex nut	14.0 in/lbs. ±1 in/lbs.
SMA connector	7.5 in/lbs. ±0.5 in/lbs.
WPM	7.5 in/lbs. ±0.5 in/lbs.
WPM-3	7.5 in/lbs. ±0.5 in/lbs.
WPM-4	7.5 in/lbs. ±0.5 in/lbs.
Type N connector (knurled)	hand-tight
TNC connector (knurled)	hand-tight
BNC	hand-tight

PROPER CABLE HANDLING

Never exceed the minimum bend radius specified for a cable. Guard against tight bends at the end of connector strain relief tubing, or at the ends of marker tubing where they may be less noticeable. Although cable bend may seem slight, the actual radius of the bend at the point of angular departure may be far smaller than the acceptable radius.

Never pinch, crush or drop objects on cable assemblies. Also, do not drag a cable over sharp edges as this will pinch it and cause it to exceed the minimum bend radius.
Never use a cable assembly to pull a piece of equipment. Cables and connectors are not designed to support or move equipment.

SECURING CABLES

Use toothed, rubber-lined "P-clamps" to hold cables in place. If it is necessary to use tie-wraps, use the widest possible wrap and the lowest setting on the gun to ensure the minimum pressure on the cable.

STORING CABLES

When storing cables, minimize cable "set" by coiling them in large diameters (1or 2 feet). Unroll the cable properly when it is ready to be used; do not pull the loops out hastily. Similarly, re-roll them when storing them away again.

CLEANING CONNECTOR INTERFACES

Use the following guidelines in cleaning connector interfaces:

A. Do not use chlorinated solvents including common tap water. These solvents are extremely penetrating and sometimes ruin otherwise good devices and assemblies.
B. Moisten a cotton swab with isopropyl alcohol. Roll the swab on a paper towel to remove excess.
C. Use the moistened cotton swab to wipe away debris. Do not try to dissolve the debris by overwetting the swab.
D. Repeat the cleaning process using additional swabs as necessary. If metallic particles are embedded in the dielectric, use an eyeglass and a sharp pick in an attempt to dislodge them. Swab again.
E. When satisfied that the interfaces are clean, blow them dry with dry compressed air, or preferably dry nitrogen (pressurized spray cans work well). Do not use breath.
F. Clean the mating connectors. These may be the source of debris.

Warranty

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of one year from date of shipment. During the warranty period, we will at our option, either repair or replace any product that proves to be defective.

TEGAM, Inc. warrants the calibration of this product for a period of one year from date of shipment. During this period we will recalibrate any product that does not conform to the published accuracy specification.

To exercise the warranty, contact TEGAM, Inc., 10 TEGAM Way, Geneva, Ohio 44041, phone 440-466-6100, fax 440-466-6110, M-F, 8 a.m.-5 p.m. ET. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty, or at least 90 days, whichever is longer.

Limitation of Warranty

TEGAM, Inc. warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. TEGAM, Inc shall not be liable for any indirect, special or consequential damages.

Statement of Calibration

This instrument has been inspected and tested in accordance with specifications published by TEGAM, Inc.

The accuracy and calibration of this instrument are traceable to the National Institute of Standards and Technology through equipment that is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of TEGAM, Inc.

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